

CCaLC2[©] for Windows Manual (V1.0)

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1 About CCaLC2 for Windows

CCaLC2 for Windows is the second generation of the CCaLC tool that was originally developed for Microsoft Excel. Departing away from Excel, CCaLC2 tool has been developed in C#.NET as a Microsoft Windows stand-alone desktop application, making it more robust, faster and easier to use.

2 System requirements and installation

CCaLC2 is designed for use on PCs and is not suitable for use on Mac computers. It may not run properly on non-English operating systems as well as on older versions of Windows.

2.1 Installation

The CCaLC2 application will be received as an executable file (*CCaLC2_setup.exe*) that can be run to install CCaLC2 for Windows on to your desktop computer. Run the *CCaLC2_setup.exe* file as normal and follow the onscreen instructions to install CCaLC2. This installation will automatically include all databases and case studies as integral parts of the CCaLC2 application.

3 Compatibility with first generation CCaLC (V1, V2 and V3)

Compatibility with all versions of the first generation CCaLC (versions 1 to 3) has been maintained as fully as possible. To transfer the studies from V1, V2 and V3 to CCaLC2 for Windows:

- Save the study in the CCaLC Excel tool by choosing the menu option *CF Study/Save CF study*
- Type the name of the study in the pop-up window and click OK
- Click the menu option *Share data/Export study* to CCaLC Desktop and click in the pop-up window on the study to be exported; the study will be saved in the directory chosen by the user
- Open CCaLC2 for Windows and click on the menu option *Import data/Excel CCaLC data file*; from the dialogue box that pops-up, select the file to be imported
- The imported study will automatically be displayed within CCaLC2 and any changes can be made.

4 Tool development credits

CCaLC and CCaLC2 were developed by a research group Sustainable Industrial Systems based at the University of Manchester and led by Professor Adisa Azapagic. The following researchers were involved in the project:

CCaLC2 for Windows

- Martyn Jones (software development)
- Harish Jeswani (methodology)

CCaLC (Excel-based)

- David Amienyo (case studies);
- Haruna Gujba (case studies and databases);
- Harish Jeswani (case studies and databases);
- Martyn Jones (software development)
- Anthony Morgan (software development);
- Yu Rong (software development);
- Namy Espinoza-Orias (case studies and databases); and
- Heinz Stichnothe (methodology and case studies).

For further information visit www.ccalc.org.uk or contact:
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5 Acknowledgements

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6 Introduction

The CCaLC2 application allows quick and easy estimations of environmental impacts and value added along the supply chains. It takes a life cycle approach and it enables estimation of the following environmental impacts:

- Carbon footprint (or global warming potential);
- Water footprint;
- Acidification potential;
- Eutrophication potential;
- Ozone layer depletion potential;
- Photochemical smog; and
- Human toxicity potential.

The tool has been developed with the following objectives in mind:

- to enable non-expert users to calculate the carbon footprint and other environmental impacts quickly and easily while following internationally accepted LCA standards such as ISO 14044 and PAS2050;
- to reduce the data collection effort by providing comprehensive databases;
- to help identify environmental hot-spots and improvement opportunities; and
- to enable trade-offs between environmental impacts and economic costs.

7 CCaLC2 overview

CCaLC2 for Windows has been developed in C#.NET as a Microsoft Windows desktop application. Information can be entered into the tool via user forms that are activated by clicking buttons at the top of worksheets. The user can navigate around the tool using the links provided.

Figure 1 shows the top-level layout of the tool. This represents a map of a typical product life-cycle and includes the following stages:

- Raw materials;
- Production;
- Storage;
- Use;
- Transport; and
- Waste.

The user can access any of these stages by clicking on the relevant box. The subsequent levels allow the user to modify information contained at these levels; this is described in more detail later on.

The application also makes use of a menu bar that allows you to perform a number of tasks from saving a CCaLC analysis to viewing a comparison of multiple analyses simultaneously. The functions of all the menu bar items are described later in this manual. The carbon footprint for each stage is shown in red, the value added in blue and the water usage in green.

CCaLC2 contains three databases: CCaLC, Ecoinvent and User database. The CCaLC database consists of publicly available data and data generated during the course of tool development. The Ecoinvent database is a proprietary database that is included in the CCaLC2 tool with a kind permission of Ecoinvent. User database is created and populated by the user as explained in the subsequent sections.

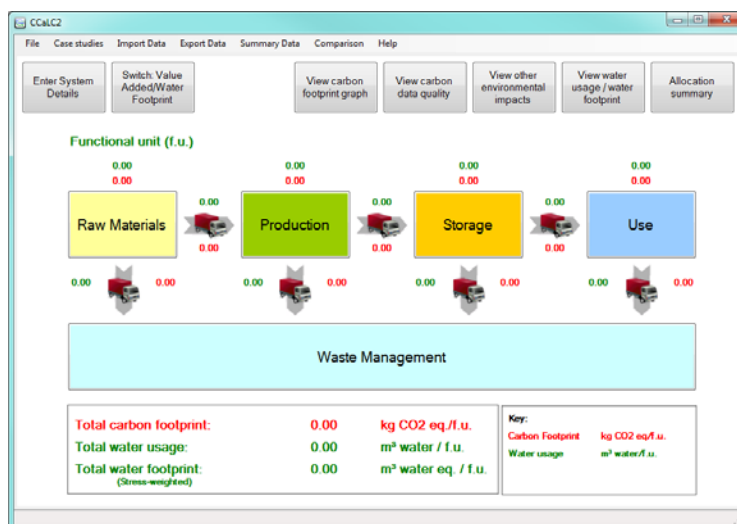


Figure 1 Top-level view in the CCaLC2 tool

8 Carbon footprint estimation

The carbon footprint of a system can be calculated in two main ways:

- by starting a new study from scratch, with all the information and data entered by the user step by step or
- by using the built-in case studies, which can be loaded up via the menu option *Case studies* and then modified according to the user specification.

The following procedure illustrates how the carbon footprint can be estimated within the CCaLC2 application, starting a study from scratch. Instructions on how to modify an existing study can be found in section 12.

8.1 Defining system details

Clicking on the *Enter System Details* button at the top of the screen at the top level activates the *System Details* user form (Figure 2). In order to proceed with the analysis, the name of the study and a functional unit must be specified. The latter relates the function of the system to a common unit, e.g. mass, energy, etc. The amount specified for the functional unit will be the amount to which the carbon footprint will be attributed. Any unit may be used in the *Unit* window but it should be noted that all other data must be directly related to this unit. For example, if the functional unit is 0.75 litres of red wine (as illustrated in Figure 2), then the data entered later on must directly correspond to the amounts of materials, energy etc. used to produce 0.75 litres of wine.

CCaLC2 - System Details

Name: Red wine

Functional Unit:

Value: 1

Units: bottle

Settings:

Mass Units: kg

Energy Units: MJ

Distance Units: km

Volume Units: m3

Monetary Units: Pound

Exchange Rate (per £): 1.00

Data Collected (yr): 2010

Data Source: Confidential

Last Updated (date): 07/01/2010

Author: CCaLC

Comments:

The functional unit is one 0.75 l bottle of wine. The system boundary is from cradle to grave. Impacts from waste management of post consumer glass packaging have been accounted for during production of packaging.

Units

☒ Change the units displayed and convert (default)

☐ Change only the units displayed

OK Cancel

Figure 2 System Details user form

The user can also define different mass (g, kg, tonne), energy (MJ, kWh, BTU), distance (km and miles), volume (m³, litres) and monetary units (£, \$, €). The default values are **tonne, kWh, km, m³** and **£**, respectively. The units can be changed at any point during the analysis. If using a currency other than £, an exchange rate should be supplied in the textbox. This enables the user to switch between different currency types during the analysis.

NB: The units are not linked to the unit of the Functional Unit defined by the user. The user should ensure that they are working in consistent units at all times.

There are two ways to convert units. This can be specified in the section Units, which lists two options (see Figure 2):

- Change the units displayed and convert (default); and
- Change only the units displayed.

The default setting on the form is to convert units. This means that, should the user change units during the analysis, all amounts already entered will be converted to the new specified unit(s). Should the user require that the amounts entered are left unchanged but only the units displayed are changed (e.g. in the event that data were entered in the wrong units), then the second options should be selected.

Other information on this form is related to the age and source of data, date of conducting the study and the author – however, these are not compulsory but may be useful for transparency and record keeping.

The system details can then be updated by clicking on the *OK* button, after which the whole system is updated.

8.2 Defining the production stage names

Once the system details have been defined, the next step is to define the production stage names. This will then enable to 'send' the raw materials to the specified stages, during the definition of Raw materials stage.

This is carried out by clicking on the *Production* box at the top level of the tool (see Figure 1) which takes the user to the individual production stages (Figure 3). In total, ten production stages can be defined.

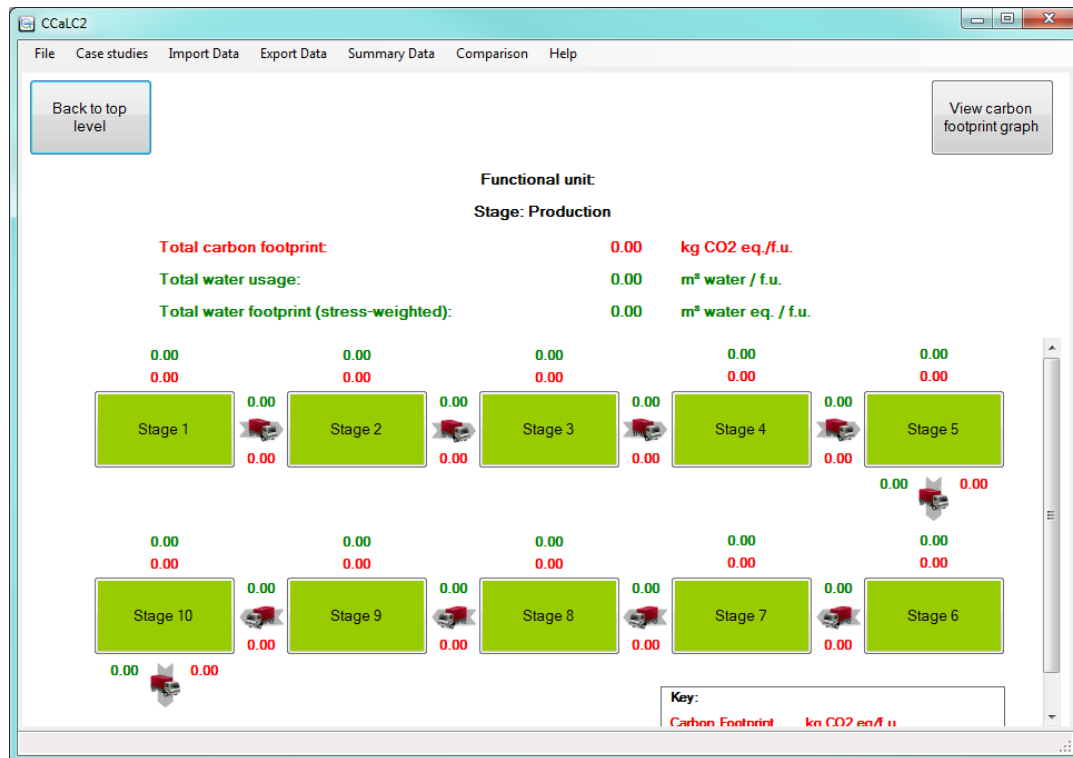


Figure 3 Overview of the Production stage

When the tool is first loaded with no study uploaded, the stage names are displayed as *Stage1*, *Stage2*...etc. (see Figure 3). The names of the stages can be defined or modified at any point during the analysis as follows:

1. Click on the stage to be modified (Figure 3); this takes the user to that stage with a number of navigation buttons at the top of the screen (as shown in Figure 4);
2. Click on the *Define Stage* button at the top of the screen;
3. Enter the name of the stage in the relevant text box
4. Enter any relevant comments in the *Comments* text box
5. Click *Update*.

Once this is done, the tool will update all instances of the stage name in the analysis. The same procedure should be carried out for the rest of the production steps, until they have all been defined. The next step is then to define the raw materials being used the different production stages.

It should be noted that the transport arrows do not connect different stages. Rather, they represent the transport of materials from an individual processing stage. Material flows may be transported between any of the processing stages – due to a large number of transport flows and combinations, it is not practical to show all the transport connections graphically, but they are captured in the transport data sheets.

Functional unit: Acrylic acid from wheat (allocation) 1 tonne

Stage: Wheat cultivation

Total carbon footprint for stage: 1164 kg CO₂ eq. / f.u.

Total costs for stage: 378.45 £ / f.u.

Material/Packaging inputs	Amount (kg)	Cost (£ / kg)	Cost (£ / f.u.)
Farm yard manure/slurry	1770	0.00	0.00
Fertiliser, K	21.9	0.00	0.00
Fertiliser, N	107	0.00	0.00
Fertiliser, P	17.4	0.00	0.00
Pesticides	0.540	0.00	0.00
Wheat, seeds	98.4	0.00	0.00
Total:	2015	Total:	0.00

Energy	Amount (MJ/f.u.)	CO ₂ eq. (kg/MJ energy)	CO ₂ eq. (kg/f.u.)	Cost (£/MJ energy)	Cost (£/f.u.)	Database section
Diesel (used in farm machinery)	4541	0.078	354	0.02	98.99	CCaLC/Energy
Total:	4541	Total:	354	Total:	98.99	

Direct emissions	Amount (kg/f.u.)	CO ₂ eq. (kg/kg GHG)	CO ₂ eq. (kg/f.u.)
Nitrous Oxide	2.72	298	810
Total:	2.72	Total:	810

Define stage: Wheat cultivation

Stage Name: Wheat cultivation

If agricultural stage, hectares used per f.u.: 0.420

Comments:

Update

Exit

Figure 4 Stage details and Define Stage user form

8.3 Defining raw materials

Raw materials are defined by clicking on the Raw Materials box on the top level of the tool (Figure 1). The user is then taken to the next level down, showing the tables related to raw materials (Figure 5).

There are four tables which will be populated as the user enters data through the user forms. The data in these four tables are related to:

- raw materials – amounts used and their carbon footprints,
- energy – any additional energy used for raw materials that is not already accounted for within the carbon footprints of the raw materials (e.g. storage and refrigeration of raw materials);
- packaging – amounts used for both raw materials and product(s), together with the carbon footprints of packaging; and
- waste from raw materials and the carbon footprints related to waste management (e.g. due to spillage or perishable nature of raw materials).

The amount of each of these can be modified by clicking on the appropriate button at the top of the screen. The carbon footprint data are also specified here, either via the databases available or by entering user carbon footprint data.

To add a raw material to the analysis:

1. Click on the *Define Materials* button (Figure 5)
2. Select the appropriate database to use (CCaLC, Ecoinvent, User-defined)

- From the first drop-down list, select type of raw material (e.g. agricultural inputs, construction materials etc.)
- Select the required material from the next drop-down list
- Select the required production stage from the second drop-down list where the raw material will be sent
- Add the amount of material per functional unit in the textbox (Note: agricultural materials are defined in mass per hectare of land)
- Select the data quality for the amount used (*high*, *medium*, *low*) to indicate how confident you are in the figure used [see Appendix 2 for a description of how the data quality is calculated for the system]
- Add any comments that are appropriate to this instance of material use (this is optional but is recommended as a reminder for future uses)
- Add the cost of the raw material, per unit mass, if needed
- Click the *Update* button.

The Raw material table on the screen will be updated to show the material name, the amount used, the carbon footprint associated with it and its destination. The database section from which the data have been selected is also shown in the tables.

The screenshot shows the CCaLC2 software interface with the 'Raw materials' stage selected. The main window displays the 'Functional unit: Red wine 1 bottle' and the 'Stage: Raw Materials'. The 'Total carbon footprint for stage' is 0.184 kg CO2 eq. / f.u., and the 'Total costs for stage' are 0.00 £ / f.u. The 'Define raw materials' dialog box is open, showing the 'Define materials' tab. The dialog box includes fields for 'Database section', 'Stage for material use', 'Amount (kg/f.u.)', 'Data quality for amount', and 'Cost (£/kg)'. It also has radio buttons for 'Agricultural inputs' and 'define inputs in terms of mass per functional unit'. The 'Details' tab is also visible, showing fields for 'kg CO2 eq./kg', 'Year', 'Location', 'Source', 'Quality of dataset', and 'Comments'.

Raw material	Amount (kg/f.u.)	CO2 eq. (kg/kg raw material)	CO2 eq. (kg/f.u.)	Cost (£/kg raw material)	Cost (£/f.u.)	Database section
Fertiliser, N	0.011	6.98	0.079	0.00	0.00	CCaLC/Materials/Agriculture
Fertiliser, P	0.028	1.86	0.052	0.00	0.00	CCaLC/Materials/Agriculture
Pesticides	0.010	5.38	0.052	0.00	0.00	CCaLC/Materials/Agriculture
sodium hydroxide, 50% in H2O	1.21E-3	1.10	1.33E-3	0.00	0.00	Ecoinvent/Materials/Chemicals
sulphur dioxide, liquid, at plant	5.60E-5	0.418	2.34E-5	0.00	0.00	Ecoinvent/Materials/Chemicals
Total	0.050	Total	0.184	Total	0.00	

Energy	Amount (MJ/f.u.)	CO2 eq. (kg/MJ energy)	CO2 eq. (kg/f.u.)	Cost (£/MJ energy)	Cost (£/f.u.)	Database section
Total	0.00	Total	0.00	Total	0.00	

Packaging	Amount (kg/f.u.)	CO2 eq. (kg/kg packaging)	CO2 eq. (kg/f.u.)	Cost (£/kg packaging)	Cost (£/f.u.)	Database section
kraft paper, unbleached, at plant	7.80E-4	0.849	N/A	N/A	N/A	Ecoinvent/Packaging
packaging glass, green, at plant	0.349	0.874	N/A	N/A	N/A	Ecoinvent/Materials/Glass
raw cork, at forest road	3.94E-3	0.020	N/A	N/A	N/A	Ecoinvent/Packaging
Total	0.00	Total	0.00	Total	0.00	

Figure 5 Raw materials stage with the *Define raw materials* user form

Other materials can be added in the same way. If a new material needs to be added to the database, then this can be done through the *Modify Database* tab. This is discussed in more detail in section 10.

The total carbon footprint for the Raw materials stage can be seen at the top of the screen in red. The costs incurred during the stage are shown in blue and if in the Water usage view, the water footprint will be shown in green.

The amount of material being used can be updated at any time or can be removed completely from the analysis by right clicking on the material name and selecting 'Edit entry' or 'Remove entry'. Alternatively by selecting that raw material in the *Define materials* user form and setting its amount to zero.

8.4 Defining transport

Transport links can be defined when there is a material to be transported between stages.

To define transport (Figure 6):

1. Click on the relevant transport box either at the top level or in the Production stage; this takes the user to the transport stage screen
2. Click the *Define Transport* button
3. A user form appears asking the user to *select* materials to be transported
4. Select the required material from the list box
5. Click on *Define Transport*. The *Define Transport* user form will then be shown (see Figure 7)
6. Choose the desired database (CCaLC or Ecoinvent)
7. Select the type of transport from the drop-down menu (e.g. *40 t – truck*)
8. Enter the distance travelled into the text box (*note the units required*)
9. Enter the estimated packing density of the material into the text box (if not known – leave as the default value of 1). The packing density is only important for low density products (approx. 300 kg/m³ or less)
10. If a truck has been selected, specify whether it returns back empty and if so, select the check box. Selecting empty return will increase the carbon footprint for a transport option by about 60%
11. Enter the cost of the transport per functional unit (if desired)
12. Select the data quality for the distance specified (*high, medium, low*) to indicate how confident you are in the figure used
13. Click the *Update* button.

The transport table will then be updated with information related to the journey that has just been specified. Information pertaining to transport type, distance, mass transported, carbon footprint for journey and total carbon footprint for the stage as well as any costs are all shown. The database section from where the carbon footprint data were sourced is also displayed.

A journey can be modified through the user form by right clicking the material being transported in the transport table and selecting 'Edit entry'. Alternatively by selecting that journey again and changing the details. The journey can be removed in a similar way either by right clicking and selecting 'Remove entry' or by setting the distance travelled to zero.

The methodology for calculating the carbon footprint of transport is given in Appendix 1.

NB Note that the transport within the Production stage is not shown on the top level view. The top level only shows the transport of raw materials into the production stage and then out of the production stage. Therefore, the carbon footprint for the transport within the Production stage is not displayed; however, it

is shown in the relevant graphs and can also be viewed via the CF Summary menu option. Transport steps within the Production stage can also be only modified from the relevant production stage rather than from the top-level view.

CCaLC2: Red wine.ccalc

File Case studies Import Data Export Data Summary Data Comparison Help

Back to top level Define transport View graph

Functional unit:
Transport stage: Raw Materials -> Processing

Total carbon footprint for stage: 0.00 kg CO2 eq./f.u.
Total costs for stage: 0.00 £ / f.u.

Material Transported	Transport Type	Distance (km)	Mass transported (kg)	CO2 eq. (kg/f.u.)	Empty return trip?	Cost (£)	Database section
				Total: 0.00	Total: 0.00		

Select material to define transport for:

- Pesticides -> Production - Grape cultivation and harvest
- Fertiliser, P -> Production - Grape cultivation and harvest
- Fertiliser, N -> Production - Grape cultivation and harvest
- sodium hydroxide, 50% in H2O, production mix, at plant -> Production
- sulphur dioxide, liquid, at plant -> Production - Wine production and b

Define Exit

Figure 6 View of the Transport stage and a user form for defining transport

Define transport:

Define materials Modify database Search database

☒ CCaLC database ☐ Ecoinvent database ☐ User-defined

Transport type: 22 truck Distance (km): 120

Packing density kg/m³: 1.00

Empty return trip? ☐

Data quality for amount: Medium

Cost of transport (£/f.u.):

Comments on amount used: Update

Details Impacts

kg CO2 eq./kg-km: 5.822e-005

Year: 2004

Location: Europe

Source: ILCD

Quality of dataset: High

Comments:

Lorry transport: Euro 0, 1, 2, 3, 4 mix; 22 t total weight, 17.3 t max payload, 85% utilisation ratio. Data from: European Reference Life Cycle Database (ILCD), European Commission - Joint Research Centre.

Exit

Figure 7 Define Transport user form

8.5 Defining the production stage

The details of the production stages can be defined by specifying each individual production stage in turn (see section 7 for how to navigate in this stage). Once the raw materials have been defined, they will be showing as inputs into the production stages where they are being used. This can be viewed by clicking on Production box from the top level of the tool and then clicking on the individual stage of interest. This takes the user to the tables which show the raw materials input to that stage (see Figure 4).

8.5.1 Defining energy use

Energy use for the production (as well as other life cycle stages) can be defined by clicking the *Define Energy* button. The associated user form is shown in Figure 8.

The energy is defined as follows:

1. Select the required database (CCaLC or Ecoinvent)
2. Select the required energy type from the drop-down menu
3. Enter the amount used in the text box (NB: make sure the correct units are being used)
4. Select the data quality for the amount being specified to indicate how confident you are in the figure used (*high, medium, low*)
5. Enter the cost per unit of energy being used (if needed)
6. Include any relevant comments in the comments box (this is optional but is recommended as a reminder for future uses)
7. Click on the *Update* button.

The energy table on the screen will be updated with the relevant information and the carbon footprint and associated cost shown. The database from where the data were selected is also displayed.

Figure 8 Define Energy user form

8.5.2 Defining land use change

If following the PAS2050 guidelines, land use change relevant to the functional unit that has occurred during the last 20 years must be accounted for in the analysis. Land use change can be defined in any of the production stages as well as in the raw materials stage. The procedure is as follows (see Figure 9):

1. Click the *Define land use change* button in any Production or Raw material stage
2. From the drop-down list, select the country where the land use change has taken place
3. From the drop-down list, select the current land use (*annual cropland, perennial cropland*)
4. From the drop-down list, select the previous land use (*forest land, grassland*)
5. Enter the area of land changed per functional unit (*hectares*)
6. Enter the time the land is used for per functional unit (*years or pro-rata months expressed in years*)
7. Select the data quality for steps 5 and 6 above (*high, medium, low*) to indicate how confident you are in the figures used
8. Click *Update*.

Figure 9 Land use change form

8.5.3 Defining direct emissions

Direct emissions arising from the production as well as storage and use stages can be defined using the *Define stage* button in any of the production stages or the *Define storage/Define use* buttons in the storage and use stages, respectively. The user can define either direct greenhouse gas emissions and/or emissions of other substances that are relevant to other impact categories. Figure 10 and Figure 11 show the appropriate user forms. Direct greenhouse gas emissions can be defined as follows:

1. Select the gas emitted from the list of greenhouse gases
2. Enter the amount
3. Click *Update*.

Figure 10 Defining direct GHG emissions

Other emissions can be defined as follows:

1. Select the medium in which the emissions occur (*air, fresh water, marine water, industrial soil, agricultural soil*)
2. Select the substance emitted
3. Enter the amount emitted
4. Select the data quality (*high, medium, low*) to indicate how confident you are in the amount specified
5. Click *Update*.

Define stage: Wheat cultivation

Details | Output | GHG emissions | All emissions

Define all emissions directly emitted from stage:

Emissions to:
 marine water

Substance:
 1,1,1-trichloroethane

Amount (kg/f.u.)
 12

Data quality for amount
 Medium

Details

Carbon footprint (kg CO ₂ eq./kg):	0.00
Acidification potential (kg SO ₂ eq./kg):	0.00
Eutrophication potential (kg phosphate eq./kg):	0.00
Ozone layer depletion potential (kg R11 eq./kg):	0.00
Photochemical smog potential (kg ethene eq./kg):	0.00
Human toxicity potential (kg dichlorobenzene eq./kg):	9.65

Update

Exit

Figure 11 Defining other direct emissions

8.5.4 Defining packaging use

Packaging use for the production stage as well as any other stage can be defined by clicking the *Define Packaging* button in raw material stage. The associated user form is shown in Figure 12. Four databases exist for packaging: CCaLC food/drink, CCaLC other, Ecoinvent and User-defined.

Packaging can be defined as follows (Figure 12):

1. Select the required database (CCaLC food/drink; CCaLC other; Ecoinvent; User-defined)
2. Select the required packaging type from the drop-down menu

3. Select the processing stage for packaging from the drop-down menu
4. Select whether the packaging is required for raw material or for products Enter the amount used in the text box
5. Select the data quality of the amount being specified (*high, medium, low*) to indicate how confident you are in the figure used
6. Enter the cost per unit of packaging (if needed)
7. Include any relevant comments in the comments box (as a reminder for any future uses)
8. Click on the *Update* button.

The packaging table for the stage is then populated. Packaging types can be modified or removed from the analysis by right clicking on the packaging name and selecting 'Edit entry' or 'Remove entry'. Alternatively by selecting the packaging type and changing the details or setting the mass to zero, respectively.

Figure 12 Define Packaging user form

8.5.5 Defining waste

Waste use for the production as well as the other stages can be defined using the same procedure as for defining materials, energy or packaging. The user form is similar to those used for other life cycle stages and is shown in Figure 13.

The procedure for defining waste is as follows:

1. Select the required database (CCaLC, Ecoinvent or User-defined)
2. Select the required waste type from the drop-down menu
3. Enter the amount of waste in the text box
4. Select the data quality of the amount being used (*high, medium, low*) to indicate how confident you are in the figure used
5. Enter the cost of the waste per unit mass (if needed)
6. Include any relevant comments in the comments box (as a reminder for future uses)
7. Click on the *Update* button.

Figure 13 Define waste user form

8.5.6 Linking waste to raw materials

Waste can be linked to raw materials to allow the user to update automatically the amount of raw materials used when the amount of waste at a particular stage is changed (e.g. due to efficiency improvements). This feature is useful if a large number of raw materials are being used as it saves having to go back and update them manually if the waste amount changes.

To use this feature:

- click on the *Link waste* tab on the Waste user form (see Figure 14a). Two text boxes are shown on the form. The top box shows the list of waste streams used at this stage of the analysis that can be linked to materials used at that stage. The bottom box shows the list of materials that are currently linked.
- click on the *Modify material links* button to link a raw material to waste. This brings up a separate user-form that allows the user to create and remove links using the

appropriate buttons (Figure 14b). The top box in this user form shows raw materials used at this stage and the bottom box shows the existing material links for the waste stream selected. In this case *Wheat – UK* is the only material available to link.

a) Link waste tab

b) Create/delete links form

Figure 14 Link waste forms

The user will not initially see any effects of material linking. However, if the amount of waste being used is changed, then the raw materials linked to it will be updated to reflect that change. For instance, if the amount of waste at this stage was 0.1 kg when the material was linked, and it was increased to 0.2 kg, the amount of raw material, in this case *Wheat UK*, would be increased by 0.1 kg.

If multiple materials are linked to a waste stream, then the amounts are adjusted in proportion to the ratio of their use. For instance:

If three materials are linked to one waste stream:

Landfill Municipal = 1 kg

Material 1 = 4 kg

Material 2 = 4 kg

Material 3 = 2 kg

Then, increasing the amount of waste would have the following effect:

Landfill Municipal = 2 kg

Material 1 = 4 kg + 0.4 kg = 4.4 kg

Material 2 = 4 kg + 0.4 kg = 4.4 kg

Material 3 = 2 kg + 0.2 kg = 2.2 kg

8.5.7 Defining production stage outputs

Outputs from the production stages as well as storage can be defined in terms of mass or energy flows.

To define outputs from a stage:

1. Click on the *Define stage* button to bring up the user form (Figure 15)
2. Select the *Output* tab
3. Decide whether to define a product or a co-product (note that a product must be defined; defining co-products is optional, depending on the system being studied)
4. Type the name of the output flow into the drop down box provided (the material can be selected later on as well as its mass changed). **NB: Each output flow or co-product must have a different name even if they go through stages unchanged – this is to allow the system to distinguish between the flows in different stages**
5. If appropriate, select the destination stage for product mass flow. **NB: The product can be treated as either an intermediate product and sent on to another production stage (or storage or use) or a final product if sent to the use stage. Co-products do not have a destination as they are assumed to leave the system at that point, but they may be used for the purposes of allocation (see section 0). Energy outputs do not have a destination either and co-products defined as energy outputs may be used for the purposes of economic or energy allocation (see section 0).**
6. Add the amount of output to the text box
7. Add the value of the output (in desired)
8. If you wish to perform energy allocation at a later point, define the Lower Heating Value of any mass outputs; similarly, if you wish to perform economic allocation, the costs/values of all products and co-products must be defined
9. Click the *Update* button.

Once a mass output has been created, it will show up in the relevant transport stage as well as in the material inputs table of the appropriate stage (production, storage or use).

Define stage: Wheat cultivation

Details Output **GHG emissions** All emissions

Modify existing output streams or create new streams:

Product

Output: Wheat

Define product in terms of mass or energy:

☒ Mass ☐ Energy

Destination: Natural drying

Amount (tonne/f.u.) 4.49

Value (£/tonne) 87.00

Update

Co-product

Output:

Define product in terms of mass or energy:

☒ Mass ☐ Energy

Amount (tonne/f.u.)

Value (£/tonne)

Update

Energy allocation

If it is intended to perform energy allocation, then enter the lower heating value of the product or co-product here.

Lower heating value (MJ/kg) 14.514

Exit

Figure 15 Output tab on the Define stage user form

Note that it may be necessary to create a mass output from a stage for two reasons:

1. Transport can only be defined if there is a material flow between stages
2. Each stage is mass-balanced. Material outputs show up as a mass input at its destination stage. However, mass-balances are shown for information only and will not stop the tool from working.

8.6 Defining the storage stage

The storage stage is defined in a similar way to the productions stage – see section Defining the production stage

8.7 Defining the use stage

Several feature of the use stage make it a unique stage within the analysis. These are described below.

8.7.1 Defining appliance use

Often during the use phase of a product, it is necessary to use an appliance (e.g. for food preparation or laundry washing). To aid these analyses, the CCaLC2 tool contains databases for refrigeration, washing machines and ovens.

Appliance use can be defined as follows (Figure 16):

1. Click the *Define use* button
2. Select the appropriate database (*Fridges/Freezers, Washing machines/Dryers, Electric Ovens/Others*)
3. Select the appropriate appliance
4. Enter the appropriate data regarding *storage time, volume, cooking time* etc.
5. Select the data quality (*high, medium, low*) to indicate the level of confidence in the amount specified
6. Enter the carbon footprint per unit energy (*The default value is for the UK grid. Other values can be found in the energy database if needed*).
7. Enter the cost of the energy (if needed)
8. Click Update.

Figure 16 Appliances user form

8.7.2 Defining biogenic carbon storage/uptake in products

The impact on the carbon footprint of biogenic carbon storage or carbon uptake in products can be accounted for in CCaLC2. The impact of this reflects the weighted average time of storage during a 100-year assessment period. Two carbon storage cases may be defined:

- a specific case of biogenic carbon storage following product formation; and
- a general case of biogenic carbon storage or carbon uptake.

For a specific case where the carbon storage benefit of a product exists between 2 and 25 years after product formation (and no carbon storage benefit exists after that time), the weighting factor applied is as follows:

$$\text{Weighting factor} = (0.76 \times t_0)/100$$

where t_0 is the number of years the full carbon storage benefit of the product exists following its formation.

For a general case, the weighting factor to be applied to the CO₂ storage benefit over the 100-year assessment period is calculated as follows:

$$\text{Weighting factor} = \sum_{i=1}^{i=100} x_i \div 100$$

where i is each year in which storage occurs and x is the proportion of total storage remaining in any year i .

For further descriptions of these calculation methods, see PAS2050, Annex C.

Carbon storage can be defined in CCaLC2 as follows (Figure 17):

1. Choose either a specific or a general case
2. If a specific case, select a storage time from the drop down list
3. If a general case, calculate a weighting factor using the methodology in the PAS2050
4. Enter the amount of carbon stored
5. Select the data quality (*high, medium, low*) to indicate the confidence level in the amount specified
6. Click *Update*.

The amount of carbon stored will be shown on the use stage worksheet and the total deducted from the carbon footprint at that stage.

Figure 17 Carbon storage

8.7.3 Defining carbon release from product disposal

In cases where the disposal of a product is not immediate, it may be appropriate to apply a weighting factor to the carbon footprint of the waste stream in order to account for carbon stored up to that point. Two end-of-life scenarios can be defined:

- a specific case for a delayed single release and
- a general case for a delayed release.

For a specific case where the disposal of a product occurs between 2 and 25 years after product formation, the weighting factor applied is as follows:

$$\text{Weighting factor} = (100 - (0.76 \times t_0)) / 100$$

where t_0 is the number of years between product formation and the single release of emissions.

For a general case where releases may not occur singularly, the methodology used is as follows:

$$\text{Weighting factor} = \sum_{i=1}^{i=100} x_i (100-i) \div 100$$

where i is each year in which emissions occur and x is the proportion of total emissions occurring in any one year i . The methodology for this calculation is given in PAS2050 Annex B.

The product's end of life can be defined as follows (Figure 18):

1. Choose whether a specific or general case is being modelled
2. If a specific case, select the time to disposal from the drop down list
3. If a general case, calculate a weighting factor as described in PAS2050 and enter it in the text box
4. Select the required database (CCaLC, Ecoinvent or User-defined)

5. Select the appropriate disposal waste stream from the drop down list
6. Enter the product mass
7. Enter the cost of disposal per unit mass (if needed)
8. Select the data quality (*high, medium, low*) to indicate the confidence level for the amount specified
9. Click *Update*.

Figure 18 End-of-life user form

8.7.4 Co-product systems: system expansion and allocation

In co-product systems it is often necessary to calculate the carbon footprint of each co-product. Within CCaLC2, this can be carried out in two ways:

- by system expansion and
- by allocation (mass, energy and economic basis).

NB: The results of either system expansion or allocation are shown at the top level and not at individual stages.

To perform system expansion or allocation, click the *System expansion/allocation* button at a Production stage where co-products are produced. It is then possible to choose between system expansion and allocation by clicking on the appropriate buttons at the top of the tool. Note that, to be able to perform either operation, the co-products must first be defined (by clicking on *Define stage* and specifying co-product details; see section 8.5.7).

- System expansion

System expansion is performed by selecting a product/service that the co-product can substitute. The CCaLC2 tool then subtracts the carbon footprint of this substitute product/service from the carbon footprint of the whole system.

System expansion is carried out in CCaLC2 as follows:

1. Click on the *Perform system expansion* button
2. Select the required database (CCaLC, Ecoinvent or User-defined)
3. Select a co-product from the dialogue box that pops up; this brings up the *System Expansion* user form shown in Figure 19
4. Select a material or energy from one of the available databases
5. Enter the amount of product
6. Select the data quality (*high, medium, low*) to indicate the confidence level for the amount specified
7. Click *Update*.

The data tables are then updated and the amount to be subtracted from the carbon footprint of the whole system is shown.

- Allocation

Allocation can be carried out using mass, energy or economic basis. Allocation can be carried out in CCaLC2 as follows:

1. Click on the *Perform allocation* button; this brings up the user form shown in Figure 20
2. Select either *Mass, Energy or Economic* radio button (NB: PAS2050 requires economic allocation)
3. Click *Update* (NB: allocation can be deleted by setting the value in the Allocation text box to zero).

The allocation tables are then updated to show the allocation results. Note that to perform economic or energy allocation, all cost and energy data should be specified for all the products and co-products.

Define system expansion:

System expansion

System expansion may be performed by selecting a product (material or energy type), the function of which the Co-product displaces. See PAS2050 section 8.1.1 for further details.

The displaced product may be selected from the current

☒ CCaLC database ☐ Ecoinvent Database ☐ User-defined

Metals

Select displaced product:
Aluminium extrusion

Amount of product displaced (tonne/f.u.):
1

Data quality for amount
Medium

Update

Details

tonne CO2 eq./tonne: 2.452e+000

Year: 2005

Location: Europe

Source: ILCD

Quality of dataset: High

Comments:
Aluminium extrusion profile; primary production; production mix, at plant; aluminium semi-finished extrusion product, including primary production, transformation and recycling. The used average recycling rate is 88% for aluminium

Exit

Figure 19 System expansion user form

Define co-product allocation

Co-product allocation

Select co-product:
Straw

Allocation method:
☐ Mass ☐ Energy ☒ Economic

Allocation (tonne CO2 eq. / unit of co-product):
1.86E-4

Update

Exit

Figure 20 Allocation user form

9 Viewing carbon footprint data and results

9.1 Numerical display

Numerical carbon footprint results are displayed in red font throughout the tool. The units are expressed as *mass* per functional unit (f.u.) where *mass* is the unit specified by the user (e.g. kg, tonne, g).

Note the following:

- The total carbon footprint for the whole system is shown at the bottom of the screen on the top level of the tool
- The carbon footprint for the Raw materials, Production, Storage and Use stages is shown above the relevant box on the top level of the tool
- The breakdown of the carbon footprint for each stage can be seen in the tables by clicking on the relevant stage
- The carbon footprint of a particular material, energy, packaging, waste or transport type can be viewed in the relevant user form by clicking on Define material, energy etc.

9.2 Graphical display

Graphs showing carbon footprint results can be viewed by clicking the button *View graph of carbon footprint* at the top level of the tool. An example is shown in Figure 21.

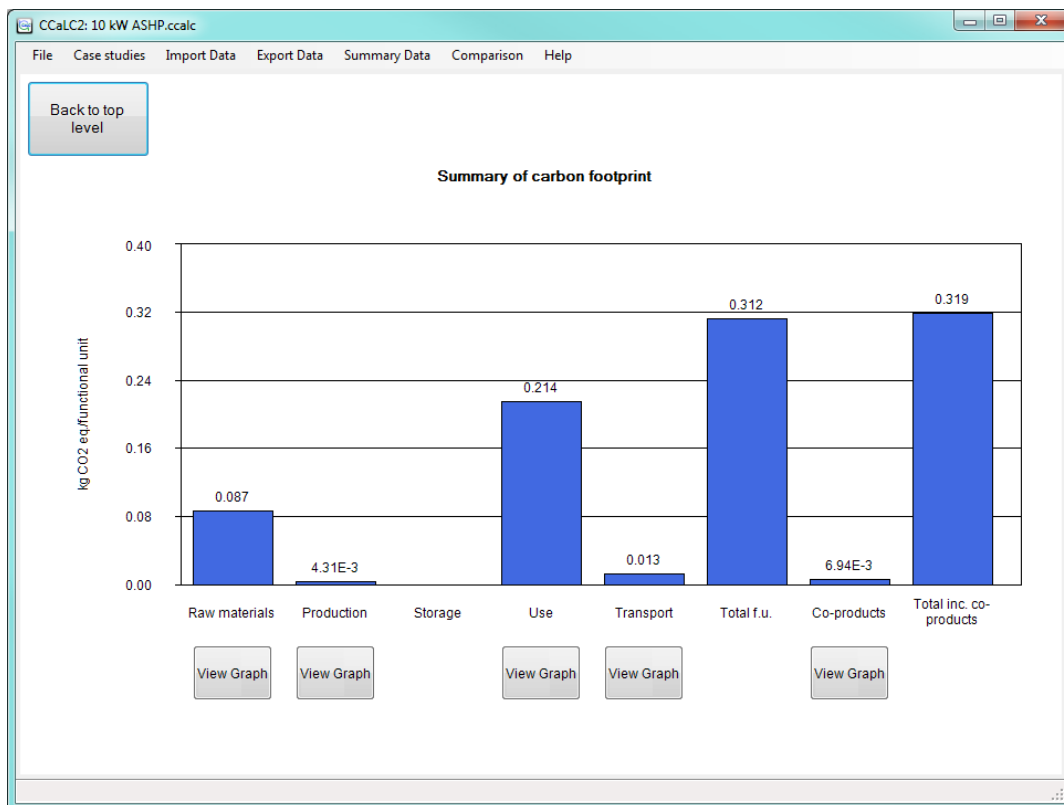


Figure 21 Graphical view of carbon footprint results at the top level of the tool

In addition, carbon footprint graphs can be viewed at each life cycle stage by clicking on the *View carbon footprint graph* button. This brings up a graph which allows drilling down to see the breakdown of each material, production stage, etc. (see the example for the Production stage in Figure 22).

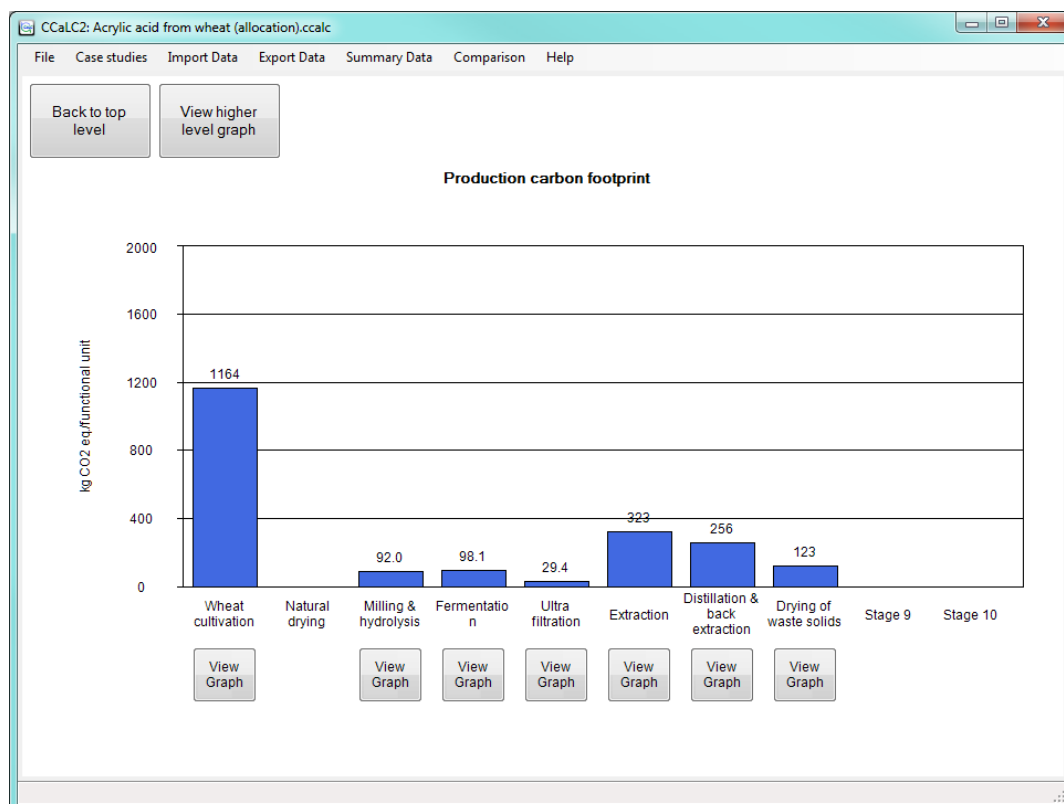


Figure 22 Carbon footprint for production stages

10 Modifying user carbon footprint databases

User-defined data can be added, modified and deleted, as explained below. The databases that come with the tool cannot be deleted or changed in any way.

10.1 Creating a new user database item

User data can be added in the CCaLC2 tool. This can be done for any of the following: materials, energy, packaging, waste and transport.

New data item can be created by:

- Selecting the *Modify Database* tab on the appropriate user form (see Figure 23 for a Raw materials example – to get there, click on the *Raw Materials* box from the top level view, then on the *Define Materials* button at the top of the screen and then on the *Modify Database* tab; the same applies for all other databases, i.e. energy, waste, packaging and transport)
- Clicking the *Create new item* button
- Filling in the appropriate fields in the resulting user form (see Figure 24).

Once created, the item will be shown in the relevant database.

NB:

- It is not possible to create a data item with a name that already exists in the database. Similarly, once created, the name of the user data item cannot be changed. If a name change is required, the user is advised to delete the item and then recreate it.
- The user-defined data can be found under the *User defined* database (see Figure 25).

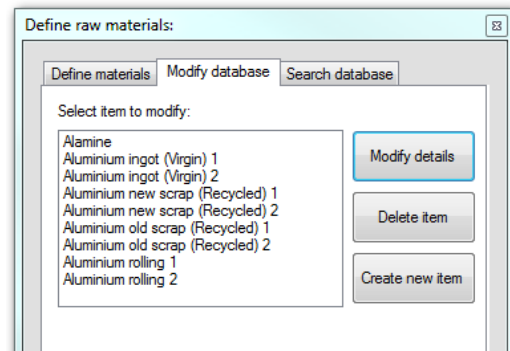


Figure 23 Modify database tab (for the Raw materials stage)

 The screenshot shows a window titled 'Create new database record:'. It has a 'Details' tab. The form contains the following fields: 'Name:' (text box), 'Carbon footprint (kg CO2 eq./kg):' (text box), 'Acidification potential (kg SO2 eq./kg):' (text box), 'Eutrophication potential (kg phosphate eq./kg):' (text box), 'Ozone layer depletion potential (kg R11 eq./kg):' (text box), 'Photochemical smog potential (kg ethene eq./kg):' (text box), 'Human toxicity potential (kg dichlorobenzene eq./kg):' (text box), 'Year:' (text box), 'Location:' (text box), 'Source:' (text box), 'Data Quality:' (dropdown menu), and 'Comments:' (text area). At the bottom are two buttons: 'Update database' and 'Exit'.

Figure 24 Create new item form

Figure 25 Materials database: user-defined data items are placed in the *User defined* database

10.2 Modifying an existing user database item

To modify a user-created data item:

- Click on the button *Define ...* (e.g. *Modify Materials*)
- Click on the *Modify Database* button; this will show a list of the existing user-created items
- Select the item to be modified and then click on the *Modify Details* button; this brings up the form with the details for that item (see Figure 26)
- Change the details as desired and then press the *Update database* button.

Create new database record:

Details

Name: Aluminium ingot (Virgin) 3

Carbon footprint (kg CO2 eq./kg): 9.85

Acidification potential (kg SO2 eq./kg): 0

Eutrophication potential (kg phosphate eq./kg): 0

Ozone layer depletion potential (kg R11 eq./kg): 0

Photochemical smog potential (kg ethene eq./kg): 0

Human toxicity potential (kg dichlorobenzene eq./kg): 0

Year: 2008

Location: Europe

Source: EAA

Data Quality:

Comments:

Update database Exit

Figure 26 Modify details for an existing user data item

10.3 Deleting a user database item

To delete a user-created data item:

- Select the item to be modified
- Click on the *Delete item* button; this brings up a warning on whether the user wants to delete the item
- Click Yes to update the database.

NB: Database items that are in use in the study active at the time of the attempted deletion cannot be deleted. The databases that come with the tool cannot be deleted either.

10.4 Sharing user database items

Individual user database items or the entire user database can be exported from one copy of CCaLC2 and imported into another. To export, click on the Export Data menu bar and either select an individual item from the user-defined records or choose to export the user-defined database. A dialog window will ask where to save the .cudr (an individual user database record) or .cudd (user database) file. Once saved, this can be shared, emailed just like any windows file.

To import a user database record or entire user database, click on the Import Data menu bar and choose to import either a user defined record or user-defined database. A dialog box will allow the correct file to be chosen and importing will begin.

NB: Where a user database item is used in an analysis the relevant user database items will be automatically saved in the analysis file and be available to users who then open that analysis.

11 Carbon footprint data quality assessment

Throughout the tool, the user is required to specify the data quality for the information they are inputting. Data quality is expressed as either high, medium or low quality. Data quality is specified at two instances: for the whole data set and for the amount being specified by the user.

The data quality for a data set is specified when the data set is created and is not subject to alteration during the analysis. Data quality of the data sets supplied within the tool will largely be high, as they are from trusted sources. For user defined data sets, the user can specify the data quality when they create it.

The data quality for the amount of material, energy, travel distance etc. specified by the user has to be specified each time the user adds a new datum to the analysis. The user is required to make a judgment as to how reliable they believe their data are. For instance, if a transport distance is known then the user might choose *high* quality of data; however, if the distance is only guessed at or generic, then the data quality for this datum will be low.

The overall data quality assessment is made by weighting each data point by its contribution to the total carbon footprint. A full description of the data quality model is given in Appendix 2.

To examine the data quality for the analysis, click on the *View data quality assessment* button the top level of the tool. This brings up the data quality assessment sheet (Figure 27) which shows the overall data quality for the analysis as well as the data quality for each individual stage.

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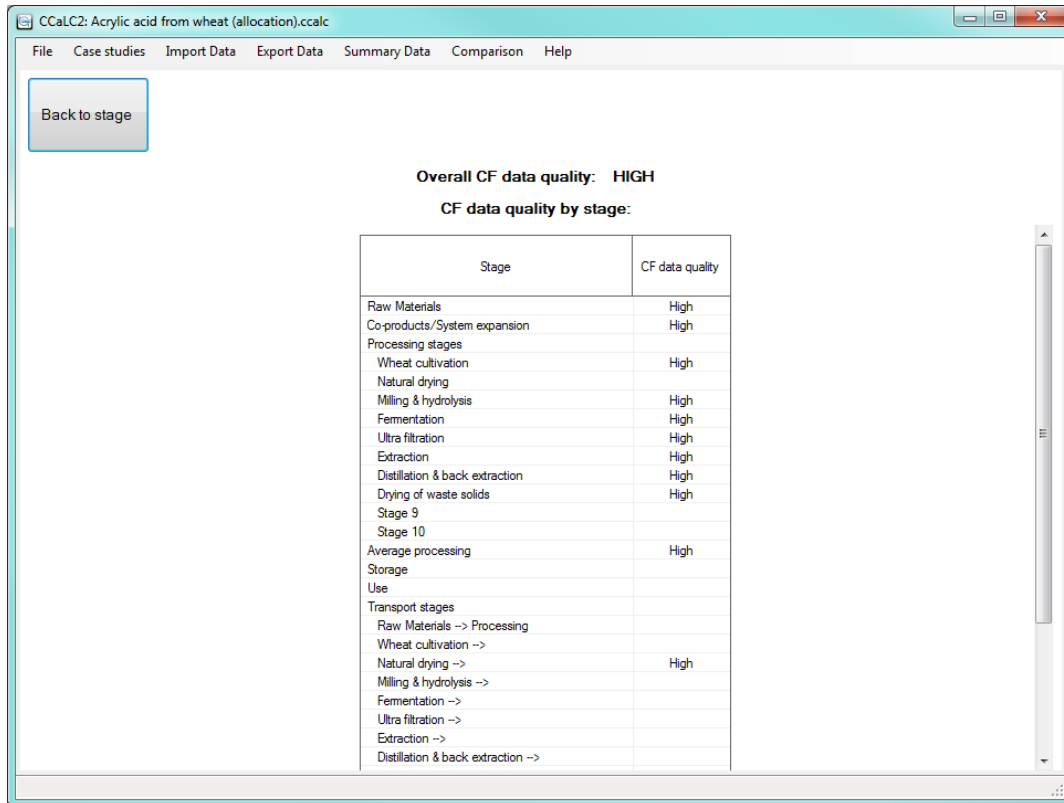


Figure 27 (Partial) View of data quality assessment screen

12 Loading, saving or starting a new carbon footprint study

An existing carbon footprinting study can be loaded, saved or deleted by using the *File* menu option at the top of the screen (see Figure 28). A new study can also be started by using the same menu option.

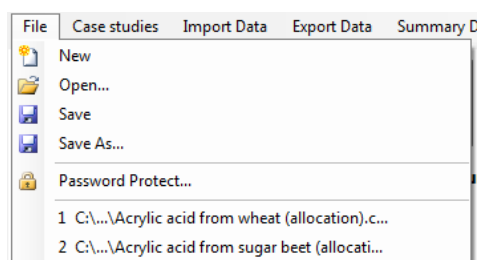


Figure 28 CF study menu options

12.1 Loading an analysis

An existing analysis can be loaded by selecting *Open...* from the *File* menu option. The user can then select the .ccalc (CCaLC analysis) file to open. Password protected files will prompt for the password to be entered before the file opens in CCaLC2. CCaLC analysis files can also be opened by double clicking on a .ccalc file, or dragging a file into the CCaLC2 application window.

NB: Loading a CF study will overwrite any data currently being used. Therefore, users are advised to save their analysis before loading another one.

12.2 Saving an analysis

To save a study, select *Save or Save As...* from the *File* menu option and select a name and location to save the .ccalc (CCaLC analysis) file. Alternatively, select a previously saved study to overwrite it with new results.

12.3 Starting a new study

A new study can be started by selecting the *New* item from the *File* menu. The user will be asked if they are sure they want to start a new study and will then be given the option of saving the existing study first.

13 Carbon footprint summary

A summary of the results of a carbon footprint study can be obtained via the *Summary Data/View CF Summary* menu option. This takes the user to a page with tables and graphs that summarise the analysis (Figure 29). The summary can be printed out by selecting *Print summary* from the CF Summary menu option.

An inventory of the materials, energy and packaging used in the analysis can be viewed by selecting the *Summary Data/View Inventory menu*. A partial view of the tables is shown in Figure 30.

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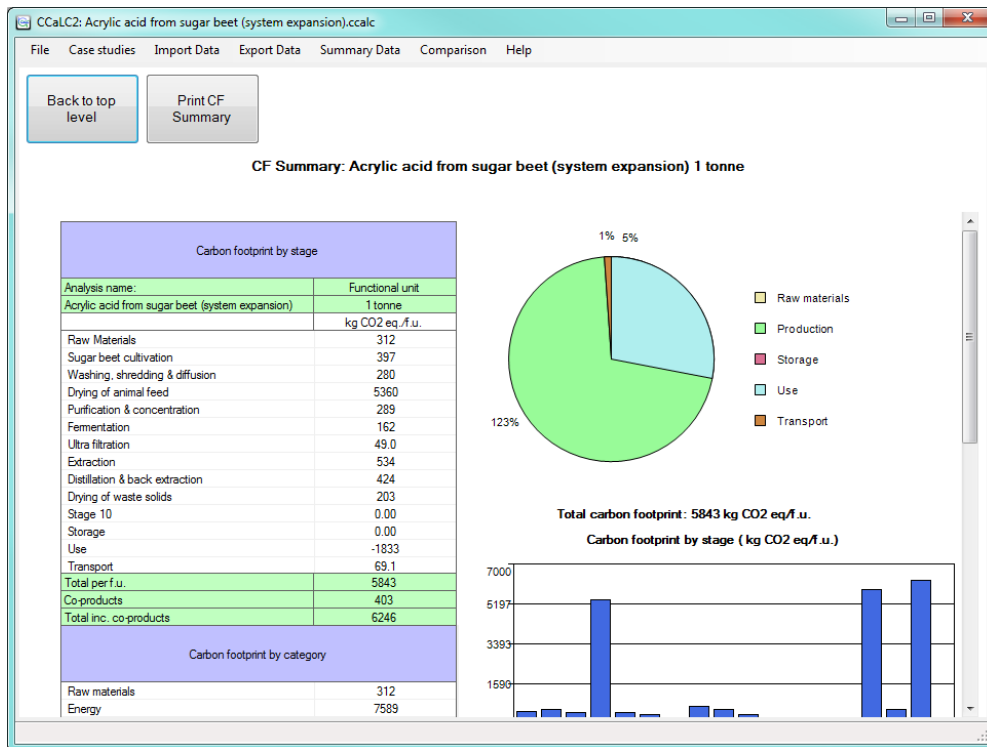


Figure 29 (Partial) View of the summary screen

Inventory analysis: Acrylic acid from sugar beet (system expansion) 1 tonne

Raw materials:	Amount (kg)	Stage:	Database section
Alamine	13.0	Extraction	CCaLC/Materials/Chemicals
Coke	20.3	Purification & concentration	CCaLC/Materials/Chemicals
Diammonium phosphate (21% conc.)	36.0	Fermentation	CCaLC/Materials/Chemicals
Farm yard manure/slurry	1078	Sugar beet cultivation	CCaLC/Materials/Agriculture
Fertiliser, K	19.9	Sugar beet cultivation	CCaLC/Materials/Agriculture
Fertiliser, N	17.6	Sugar beet cultivation	CCaLC/Materials/Agriculture
Fertiliser, P	7.86	Sugar beet cultivation	CCaLC/Materials/Agriculture
Limestone	259	Purification & concentration	CCaLC/Materials/Building materials
Octanol	13.0	Extraction	CCaLC/Materials/Chemicals
Pesticides	0.326	Sugar beet cultivation	CCaLC/Materials/Agriculture
Sugar beet, seeds	0.748	Sugar beet cultivation	CCaLC/Materials/Agriculture

Energy:	Amount (MJ)	Stage:	Database section
Diesel (used in farm machinery)	3693	Raw Materials	CCaLC/Energy
Electricity-CHP-10	144	Raw Materials	CCaLC/Energy
Electricity-CHP-10	120	Raw Materials	CCaLC/Energy
Electricity-CHP-10	28.4	Raw Materials	CCaLC/Energy
Electricity-CHP-10	423	Raw Materials	CCaLC/Energy
Electricity-CHP-10	1410	Raw Materials	CCaLC/Energy
Electricity-CHP-10	527	Raw Materials	CCaLC/Energy
Electricity-CHP-10	1271	Raw Materials	CCaLC/Energy
Electricity-CHP-10	1459	Raw Materials	CCaLC/Energy
Heat-CHP-10	3247	Raw Materials	CCaLC/Energy
Heat-CHP-10	1948	Raw Materials	CCaLC/Energy
Heat-CHP-10	9.07E+4	Raw Materials	CCaLC/Energy
Heat-CHP-10	3975	Raw Materials	CCaLC/Energy
Heat-CHP-10	9234	Raw Materials	CCaLC/Energy

Figure 30 (Partial) View of the inventory screen

14 Data comparison

Up to four analyses can be compared for either carbon footprint, water footprint, other environmental impacts or value added. This can be carried out via the *Comparison* menu and choosing the appropriate option (carbon footprint, water footprint, all impacts or value added).

To compare the alternative/different systems:

- Click the *Comparison/Appropriate option* from the menu option; this takes the user to the appropriate tables (see Figure 31 showing an example for the carbon footprint)
- If any data are shown in the tables that are not part of the desired comparison analysis, click the *Clear all data* button; this will delete any previous data that the user does not wish to consider
- Right clicking on any of the tables will bring up options to load data from the current analysis, any saved analysis or case studies.

A graphical comparison of the data in the tables can be viewed by clicking on the *View graphs* button at the top of the sheet.

CF Comparison:

Carbon footprint by stage		Carbon footprint by stage		
Analysis name:	Functional unit	Analysis name:	Functional unit	Analysis name:
Acrylic acid from sugar beet (system expansion)	1 tonne	Acrylic acid from wheat (system expansion)	1 tonne	
	kg CO2 eq./f.u.		kg CO2 eq./f.u.	
Raw Materials	312	Raw Materials	887	Raw materials
Sugar beet cultivation	397	Wheat cultivation	1164	Production - Stage 1
Washing, shredding & diffusion	280	Natural drying	0.00	Production - Stage 2
Drying of animal feed	5360	Milling & hydrolysis	92.0	Production - Stage 3
Purification & concentration	289	Drying of animal feed	82.1	Production - Stage 4
Fermentation	162	Fermentation	98.1	Production - Stage 5
Ultra filtration	49.0	Ultra filtration	29.4	Production - Stage 6
Extraction	534	Extraction	323	Production - Stage 7
Distillation & back extraction	424	Distillation & back extraction	256	Production - Stage 8
Drying of waste solids	203	Drying of waste solids	123	Production - Stage 9
Stage 10	0.00	Stage 10	0.00	Production - Stage 10
Storage	0.00	Storage	0.00	Storage
Use	-1833	Use	-1833	Use
Transport	69.1	Transport	54.0	Transport
Total perf.u.	5843	Total perf.u.	794	Total perf.u.
Co-products	403	Co-products	482	Co-products
Total inc. co-products	6246	Total inc. co-products	1276	Total inc. co-products
Carbon footprint by category		Carbon footprint by category		
Raw materials	312	Raw materials	887	Raw materials

Figure 31 (Partial) View of the carbon footprint comparison sheet

15 Sharing user-created studies and results between users

15.1 Loading and saving CCaLC2 analysis

User-created studies can be shared between users by saving and loading .ccalc (CCaLC analysis) files. Details of how to do this are in section 11.

15.2 Exporting graphs

Graphs from the analysis can be exported using the *Export data/Export graphs* menu. This creates a new workbook that contains all the graphs from the analysis. This function enables the user to change the graphs and the related data as they wish.

15.3 Exporting graph tables

Tables containing all the graph data from the analysis can be exported using the *Export data/Export graph tables* menu. This creates a new workbook that contains all the graph data from the analysis. This function enables the user to create their own graphs from the related data as they wish.

15.4 Exporting comparisons

Data from any comparisons made using the *Compare* menus can be exported using the *Export Data/Export comparisons* menu. This creates a new workbook that contains all the comparison data as well as the appropriate graphs and can be modified by the user as any other Excel file.

16 Importing data sets

16.1 Importing data using the CCaLC template

Importing data using the CCaLC template is currently disabled in CCaLC2. It is expected to be enabled in an upcoming release of CCaLC2.

16.2 Importing ILCD data

Importing ILCD data is currently disabled in CCaLC2. It is expected to be enabled in an upcoming release of CCaLC2.

17 Calculating water usage and water footprint

In addition to the carbon footprint, it is possible to estimate the impacts from water usage. Two values are estimated:

- water usage; and
- water footprints.

The former represents a simple sum of the total water usage in the life cycle of the product and the latter follows the methodology proposed by Pfister et al. (2009). The methodology used for water-related estimations is explained in Appendix 3.

The database containing the water usage data is different to that containing the main environmental impact data and the water-footprint is calculated in a separate area of the tool.

17.1 Switching between water footprint and value added

The button labelled 'Switch: Value added/Water footprint' may be used to alternate between a display of value added data (in blue) and water usage data (in green). This data is displayed in addition to the carbon footprint data (shown in red throughout).

17.2 Populating the water footprint data

By clicking on the 'View water usage/water footprint' the user is taken to the water usage screen. This is shown in Figure 32. The total water usage for the stage is shown at the top of the screen along with the water footprint data. The difference between these is discussed below. If some water data are missing, a warning is shown at the top of the screen.

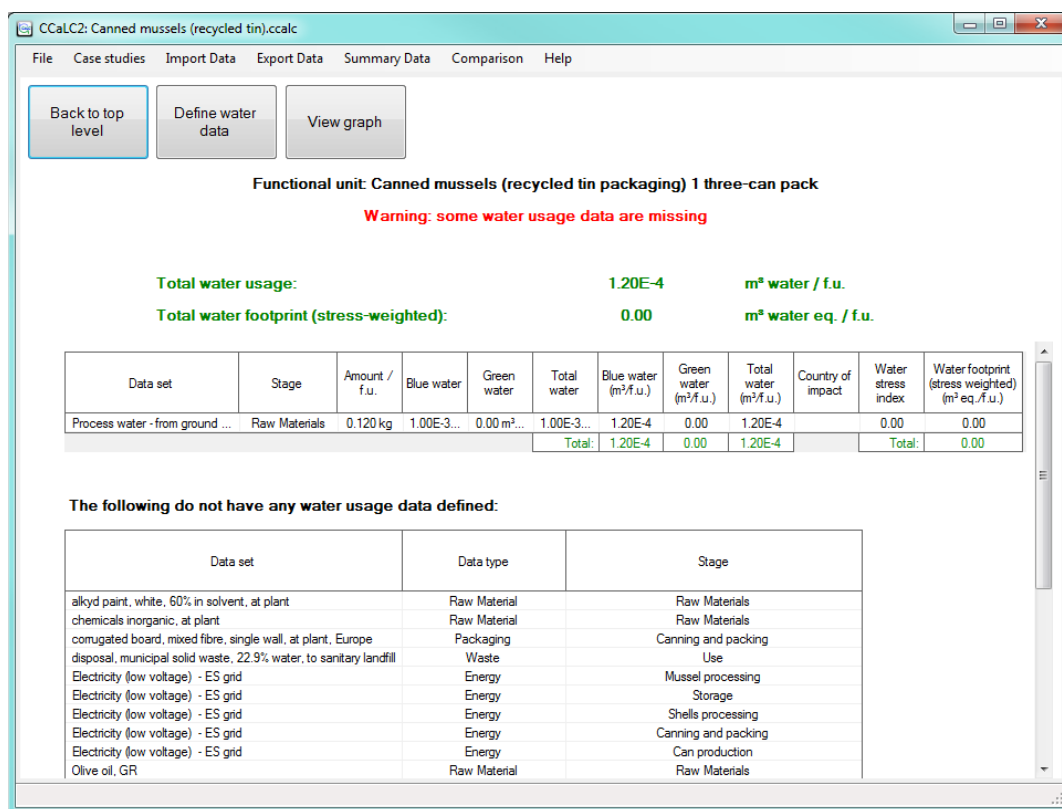


Figure 32 Water usage/footprint screen

Water usage data are defined using the *Define water data* button. This brings up the user form as shown in Figure 33a. By using the drop down menu at the top of the form, the user can select different stages. When a stage is selected, the two list boxes on the

form will be populated. The top box will show data sets at this stage that currently have no water footprint data associated with them. The bottom box shows data sets for which water usage has been defined (and may be modified). The user can define data by selecting an item from the relevant list box and clicking the *Define water usage* button. The *Define water usage for data set* form is then shown (Figure 33b).

This form allows the user to associate water usage with a particular data set. There are two options:

- to enter user water usage data or
- to select an item from the CCaLC water use database to associate with the data set.

Water is defined as blue and green water, the sum of which represents the total water usage. A brief discussion of the meanings of these terms is given in Appendix 3. The user may choose which method to use by clicking on the radio buttons near the top of the form:

- if the *Define data* button is selected, the first section of textboxes will become active and the user can simply enter water usage data in terms of m^3 per unit;
- if the *Select from CCaLC* is selected then the user can select an item from the drop-down menu that approximates the original. Water usage data and references are shown greyed out and cannot be modified.

a) Define water usage data

Select data

Select analysis stage:
Raw Materials

The following data need defining for water usage at this stage:

- alkyd paint, white, 60% in solvent, at plant
- chemicals inorganic, at plant
- Olive oil, GR
- soap, at plant
- sodium chloride, powder, at plant
- sodium hydroxide, 50% in H₂O, production mix, at plant
- Tin plate (61.7% recycled)
- Vegetable oil (sunflower seeds), NL

Define water usage

The following data may be re-defined for water usage at this stage:

- Process water - from ground water

Define water usage

Exit

b) Define water usage for data set:

Define data

Name: kraft paper, unbleached, at plant

Stage: Production - Wine production and bottling

Define country data

The water stress index for a given country is used to obtain the water footprint from the water usage data.

Country: Germany Water stress index: 0.120

Define your own data or select an approximation from the CCaLC database:

☐ Define data

☒ Select from CCaLC water use database

Select from CCaLC water use database

Paper & paperboard, other, Germany

Blue water (m ³ /kg):	6.00E-3
Green water (m ³ /kg):	0.616
Total water (m ³ /kg):	0.622
Location:	Germany
Comments:	Paper produced from pine from temp

Update

Exit

a) b)
Figure 33 Define water usage form

The drop-down menu at the top of the form contains a list of countries that have water-stress index values associated with them. This may be left blank, or a country selected in order to calculate water footprint data from the existing water usage data. The water

footprint is the product of the blue water usage for a specific data set and the water stress index. A further discussion of this is given in Appendix 3.

When the *Update* button is clicked, the water usage table is populated with data. The data is also shown in green at each of the stages in the analysis.

17.3 Missing water data

Missing water data can be viewed on the water usage/footprint screen at the bottom of the screen (see Figure 34).

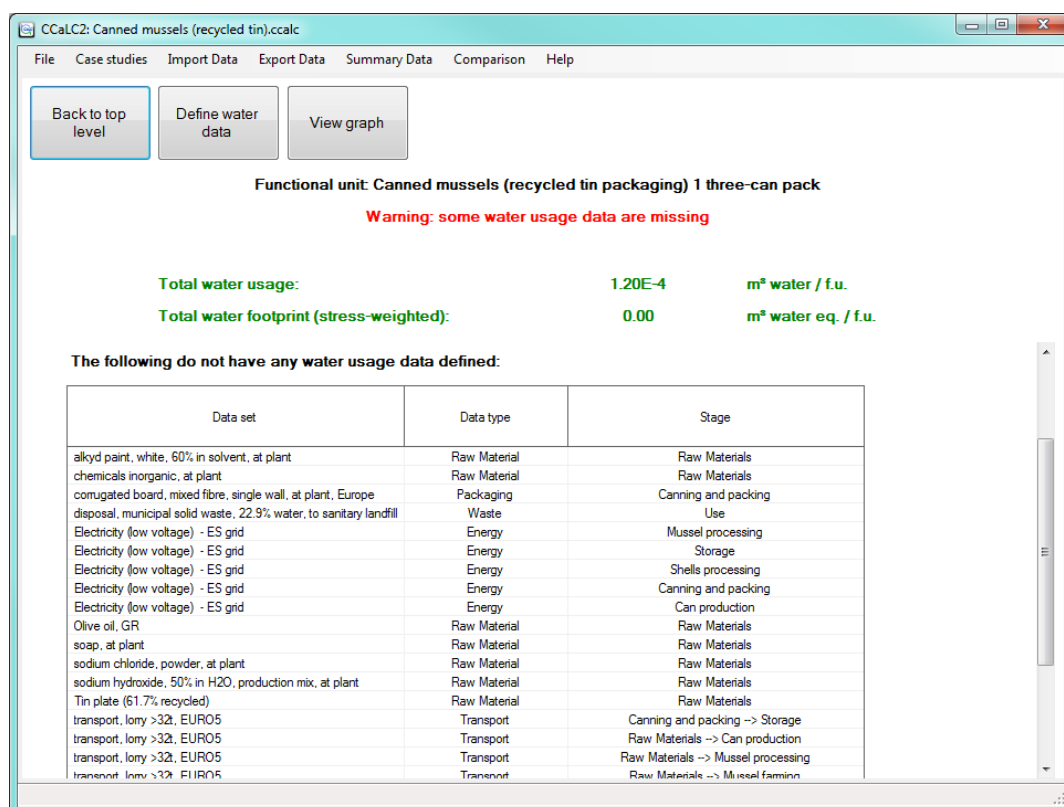


Figure 34 Table showing missing water data

17.4 Water usage graphs

Water usage and water footprint summary graphs can be viewed by clicking the *View graph* button. Graphs showing contribution of different stages to water usage are further also available.

18 Calculating other environmental impacts

In addition to the carbon and water footprints, the following other environmental impacts can be calculated in CCaLC2:

- Acidification potential
- Eutrophication potential
- Ozone depletion potential
- Photochemical ozone creation potential
- Human toxicity potential.

The results for these impacts can be seen by clicking on the *View other environmental impacts* button at the top level of the tool.

If the data for these impacts are incomplete, a message is displayed in red font, stating **'Warning: LCA data for some impacts are missing. To complete the analysis, click the button "Define other environmental impacts"'**.

If the user wishes to define the above environmental impacts, it is necessary to supply the relevant data. To do this, click on the *Define other environmental impacts* button. This brings up the form as shown in Figure 35.

Environmental impact data

The environmental impacts for the following user-defined items can be defined or modified (if no items are listed, then there are no user-defined items). To make a change, select the item of interest and double click or click the 'Modify impacts' button.

Modify impacts

The environmental impacts for the database items listed below are missing (if no items are listed, then all the impacts have been defined). Note that this is for information only as database items cannot be modified. To modify them, they would need to be re-created as user-defined data items.

Olive oil, GR
alkyd paint, white, 60% in solvent, at plant
Process water - from ground water
soap, at plant
Vegetable oil (sunflower seeds), NL
Tin plate (Spain)
sodium chloride, powder, at plant
corrugated board, mixed fibre, single wall, at plant, Europe - 2
chemicals inorganic, at plant
sodium hydroxide, 50% in H2O, production mix, at plant
transport, lorry >32t, EURO5
transport, municipal waste collection, lorry 21t
Electricity (low voltage) - ES grid
disposal, municipal solid waste, 22.9% water, to sanitary landfill

Exit

Figure 35 Modifying user data for other environmental impacts

The top text box Figure 35 shows the data sets for which other impact data are missing. To specify missing data, select a data item and then click on the *Define impact data* button.

The bottom text box shows the user defined data sets for which impact data can be modified. To modify data, select a data set and then click on the *Define impact* button. Both buttons bring up the same user form (Figure 36). The form allows the user to

specify the impact data for a specific data set by filling in the text boxes and clicking the *Update data* button.

Figure 36 Define impact data user form

19 Calculating value added

Value added can be calculated by adding cost data at various points in the analysis (e.g. while defining materials, waste, transport etc.) The value added are shown in blue font above each stage as well as in the value-added tables.

To view a summary of the value added data, click on the *View value added analysis* button at the top of the tool. This takes the user to a summary value-added table (see Figure 37). The table lists the costs in each stage and value of the outputs, along with the overall value added for the analysis. If some cost data are missing, a warning is shown in blue stating that “*Some value-added data are missing or are zero*”. The missing data can be seen by clicking the *View missing data* button (Figure 38).

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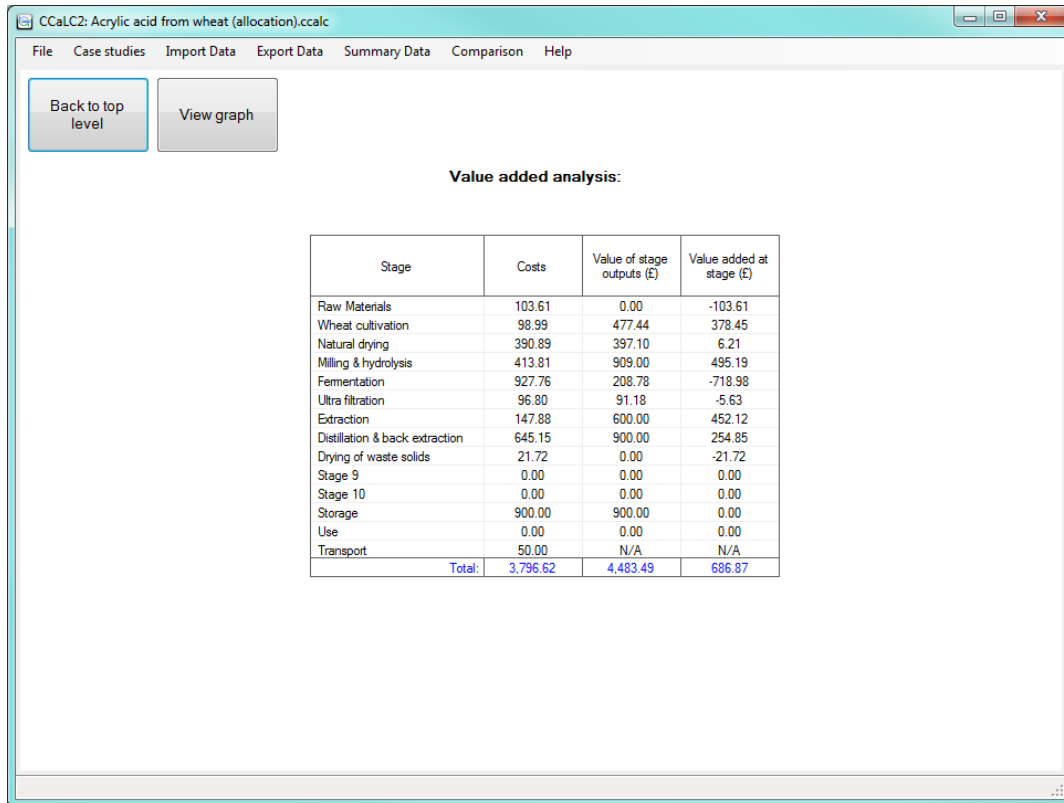


Figure 37 Value added summary

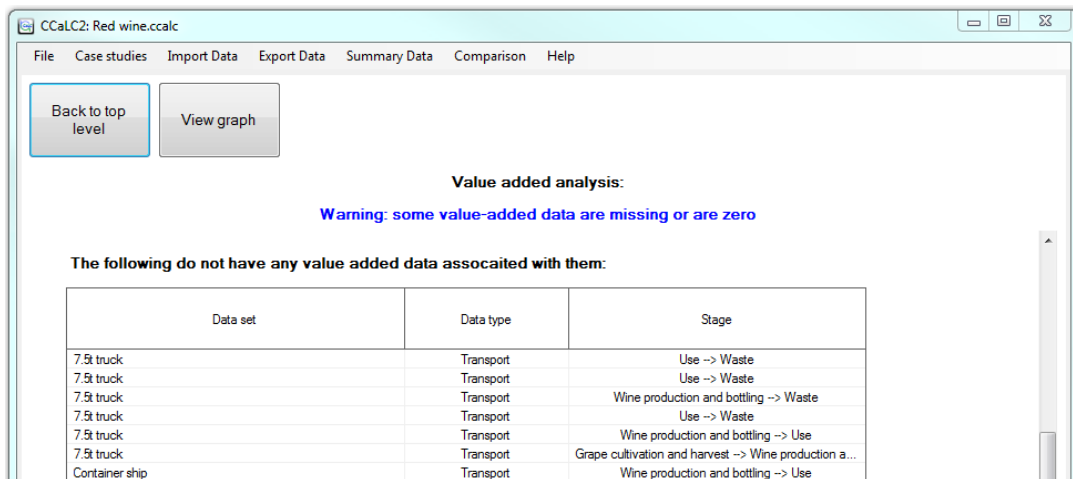


Figure 38 Summary of missing cost/value data

20 Example case studies

To aid the user in carrying out their own studies, the CCaLC2 tool has built-in 54 example case studies in the following sectors:

- Biofeedstocks and biofuels;
- Chemicals and related;
- Energy;
- Food and drink; and
- Packaging

Some of these are detailed below.

The case studies can be modified to suit the user and saved under a different name.

20.1 *Biofeedstocks: PLA from wheat*

20.1.1 Introduction

This section provides a brief description of the PLA case study based on Mortimer et al. (2009) and Mortimer et al. (2004).

The LCA study follows the ISO 14044: 2006 and PAS 2050: 2008 methodologies as far as possible. The following sections describe the goal, system boundaries and inventory data used for the case studies.

20.1.2 Goal and scope of the study

Goal of the study: The main goal of this study is to provide a carbon footprint analysis of PLA from wheat.

Functional unit: The functional unit of this study is defined as '1 tonne of PLA'.

Scope and system boundary: The system boundaries are from 'cradle-to-gate' for PLA. As shown in Figure 39, the life cycle stages include:

- raw materials extraction and production;
- wheat cultivation;
- PLA production processes (milling & hydrolysis, sterilisation and fermentation, filtration, purification & crystallisation, polymerisation & crystallisation and packaging); and
- production of co-products.

Some aspects of the life cycle supply chain are not considered due to limited data availability and they include:

- water used for agricultural and industrial processes; and
- wastewater discharged from agricultural and industrial processes; and
- transport of raw materials and waste.

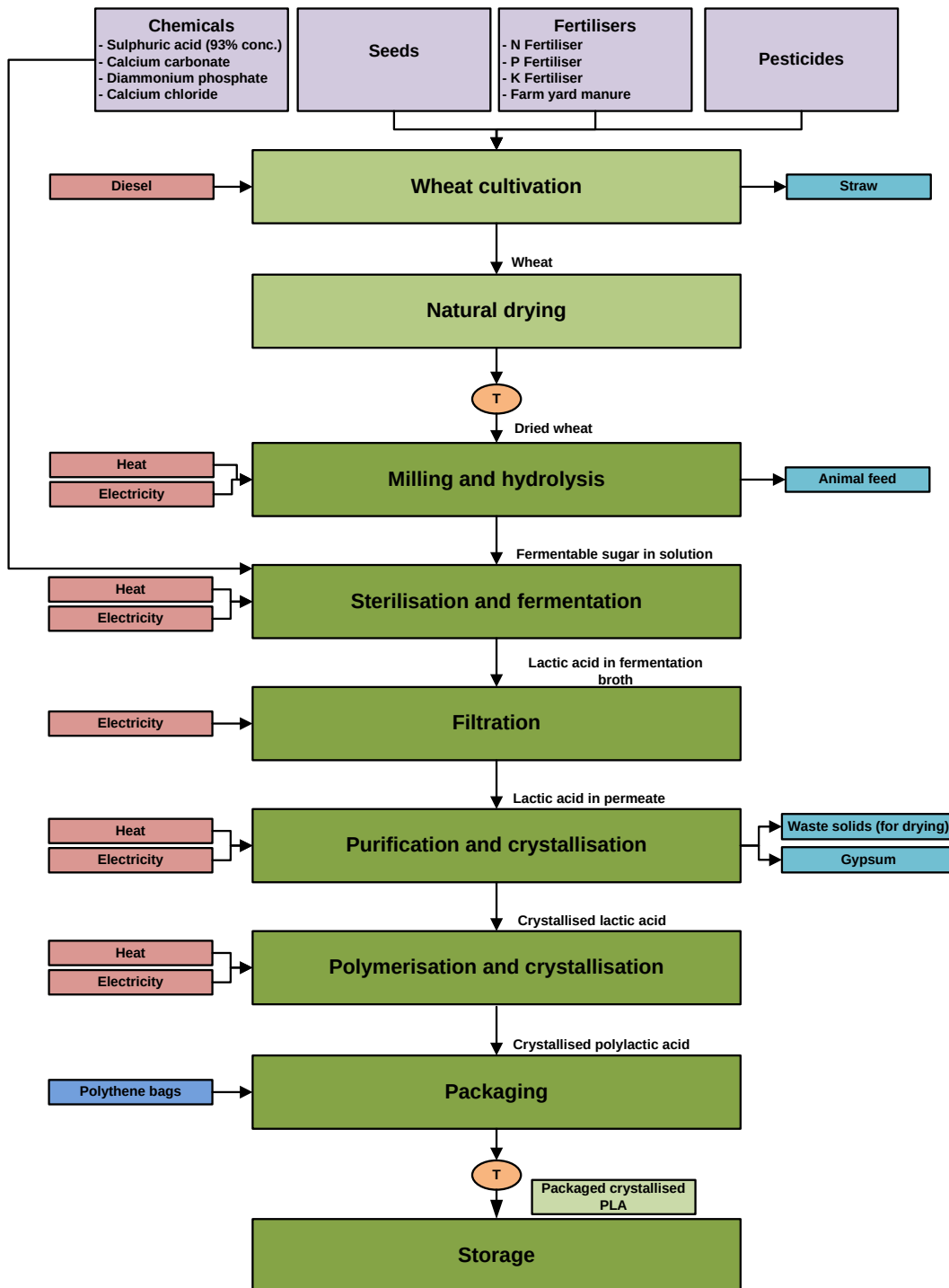


Figure 39 System boundary for PLA from wheat

20.1.3 Inventory analysis

Raw materials and energy: The inventories used for this study include the raw materials (fertilisers, pesticides and chemicals) and energy used for agricultural and industrial processes. These inventories are presented Table 1 and Table 2.

Table 1 Raw materials inventory

Raw materials	Quantity (tonne/functional unit)
Agricultural stage	
N Fertiliser	8.13E-02
Farm yard manure/slurry	1.35E+00
P Fertiliser	1.33E-02
K Fertiliser	1.67E-02
Pesticides	4.13E-04
Seeds – Wheat	7.49E-02
Production stage	
Sulphuric acid (93% conc.)	6.26E-01
Calcium Carbonate converted to CaO	4.22E-01
Diammonium phosphate (21% concentrated)	3.88E-02
Calcium chloride	1.25E-03
Packaging	
Polythene bags	0.004

Table 2 Energy inventory

Energy	Quantity (MJ/ functional unit)
Agricultural stage	
Diesel	3,457
Production stage	
Electricity	7,265
Heat	38,208

Transport: The transport distances in the life cycle stages are assumed to be as:

- Transport of wheat from farm to the PLA plant: 186 km using 40 t truck.
- Transport of PLA from farm to the storage: 450 km using 40 t truck.

Co-products: Co-products and their quantities, energy content and economic value are listed in Table 3.

Carbon storage in the product: 1.94 tonne CO₂ eq./ tonne of PLA.

Table 3 Co-products

Co-products	Quantity (tonnes)	Energy content (MJ/tonne)	Economic value (£/tonne)
Agricultural stage			
Straw	2.61	12,678	44
Production stage			
Animal feed	1.926	18,200	80
Gypsum	1.01	0	3

20.1.4 Impact assessment

The results of the carbon footprint analysis of PLA from wheat (economic allocation) as modelled in the CCaLC2 tool are shown in Figure 40. The carbon footprints are 2.22 tonne CO₂ eq., per tonne of PLA. The 'production' stage is the major 'hot spot' along the supply chains of PLA (Figure 41). This is mainly due to the use of energy in the production of PLA.

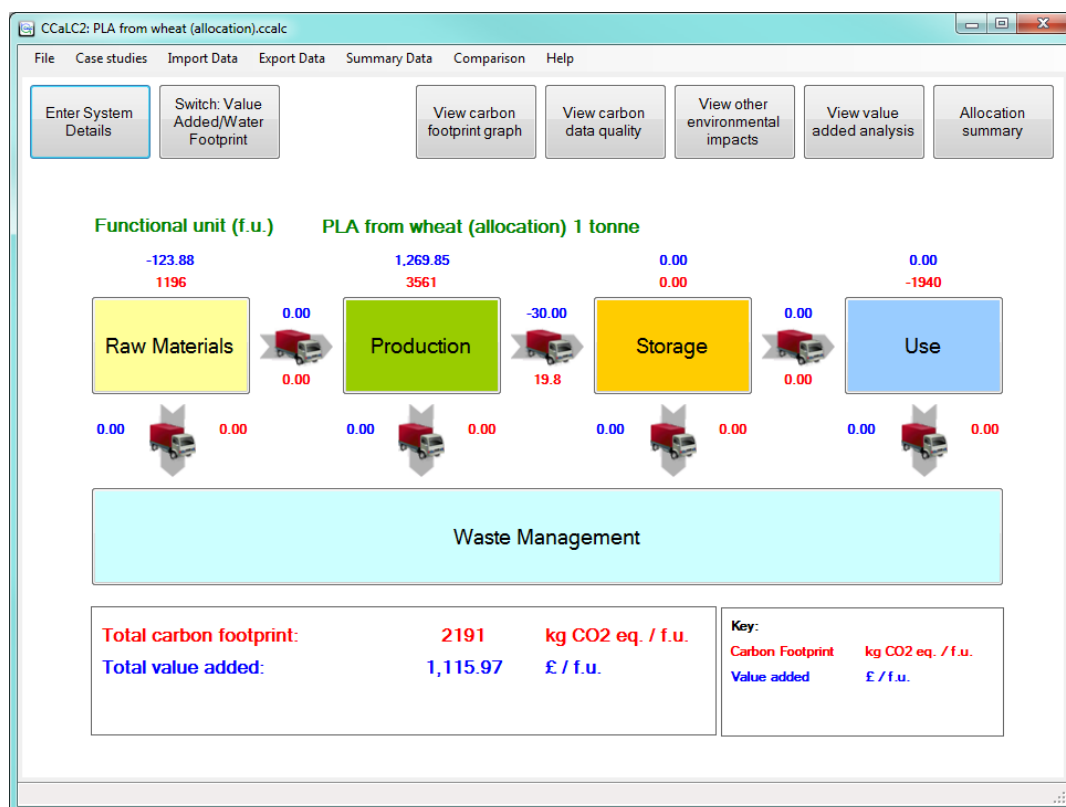


Figure 40 Carbon footprint of PLA from wheat

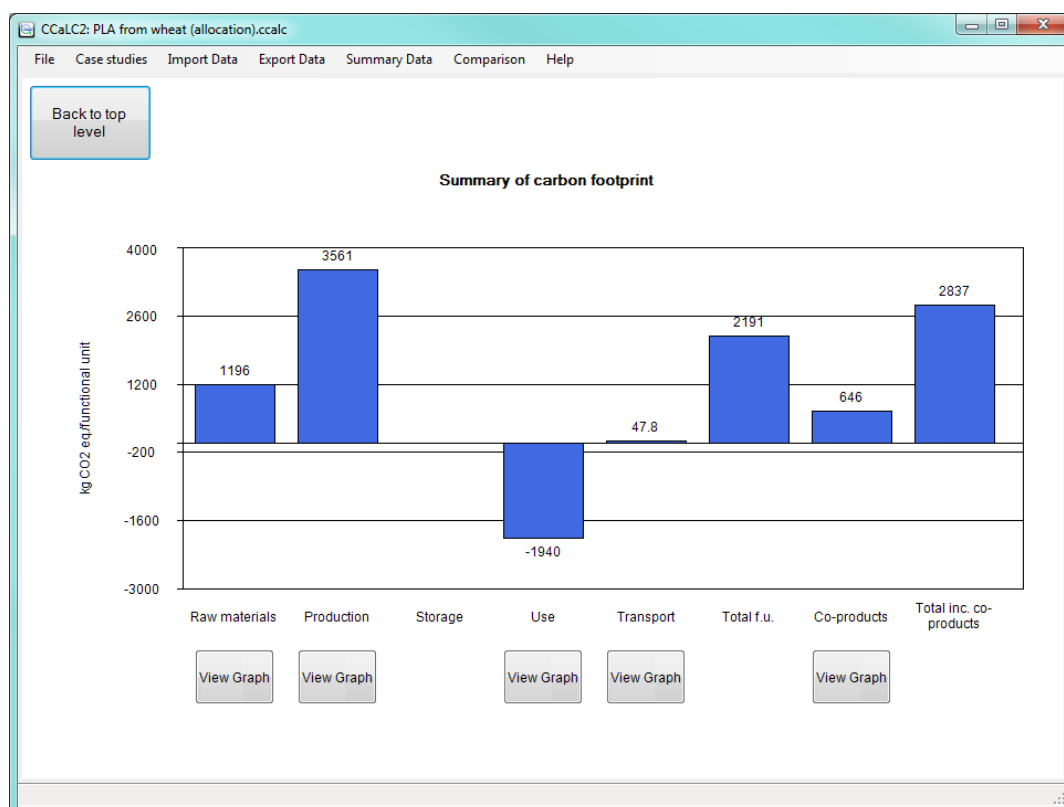


Figure 41 Contribution of life cycle stages to the total carbon footprint

References

- Mortimer, N., A. Evans, A. Ashley, C. Hatto, V. Shaw, C. Whittaker and A. Hunter (2009) Life cycle assessment workbooks for selection of major renewable chemicals, NNFCC and North Energy.
- Mortimer, N., M. Elsayed, R. Horne (2004) Energy and greenhouse gas emissions for bioethanol production from sugar beet and wheat grain, Sheffield Hallam University.

20.2 Food and drink: Lunch at a sandwich bar

20.2.1 Introduction

This report aims to provide a brief description of a food case study in the CCaLC tool. The study corresponds to the calculation of life cycle GHG emissions for a typical packed lunch consumed at a sandwich bar in the UK.

The LCA study follows the ISO 14044 and PAS 2050 methodology as far as possible. The following sections describe the goal, system boundaries and inventory data used for the case studies.

20.2.2 Goal and scope of the study

Goal of the study: The main goal of this study is to provide a carbon footprint analysis of a typical packed lunch consisting of a sandwich, potato crisps and a beverage.

Functional unit: The functional unit of this study is defined as ‘an individual serving of packed lunch consisting of a packed sandwich, a packet of potato crisps and a bottle of soft drink consumed at a sandwich bar’.

Scope and system boundary: The system boundaries of the study include ‘cradle-to-grave’ analysis for the lunch considered. As shown in Figure 42, the life cycle stages include:

- production of ingredients;
- manufacture of packaging;
- preparation of mayonnaise;
- preparation of ingredients;
- assembly of sandwich;
- consumption of lunch; and
- landfilling of waste food and packaging.

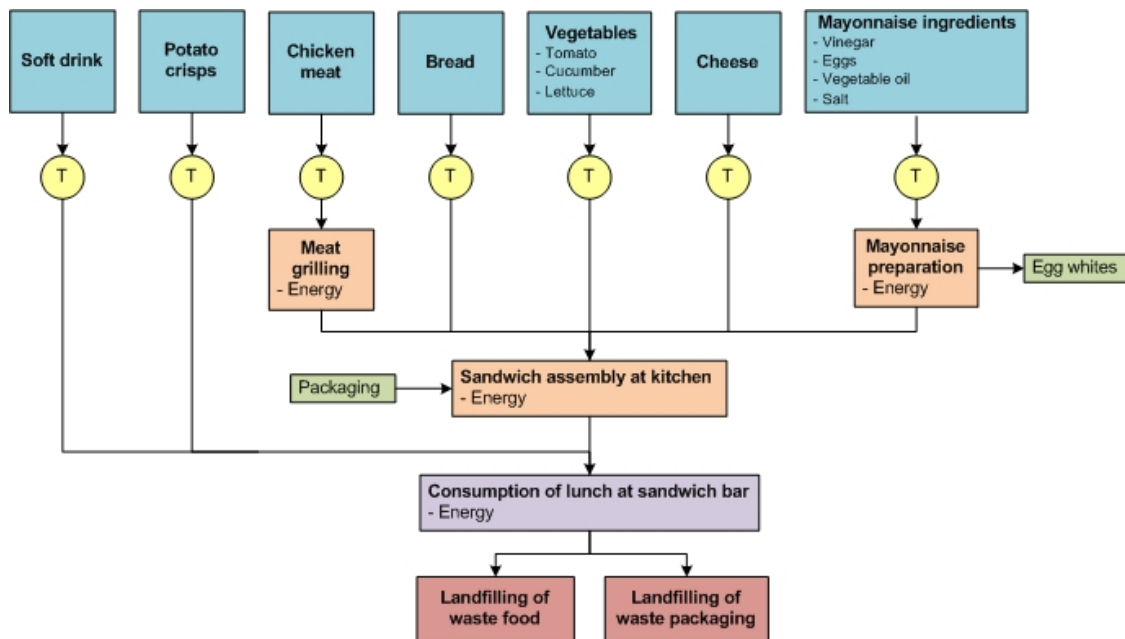


Figure 42 System boundaries for a packed lunch (T = Transport)

20.2.3 Inventory analysis

Raw materials and energy: These inventories are presented in Table 4 and Table 5.

Table 4 Materials inventory

Material	Life cycle stage	Quantity [g /functional unit]
Eggs	Mayonnaise preparation	6
Vinegar		2.20
Vegetable oil		15.2
Salt		0.3
Chicken meat	Meat grilling	60
Bread	Sandwich assembly	90
Cheese		40
Tomato		20
Lettuce		20
Cucumber		10
Potato crisps		35
Soft drink		500
Plastic packaging		12

Table 5 Energy inventory

Life cycle stage	Energy	Quantity [kWh /functional unit]
Mayonnaise preparation	Electricity	4.40 E-05
Meat grilling and kitchen operation	Electricity	1.10
Consumption at sandwich bar	Electricity	0.8

Transport: Transport of materials between life cycle stages is assumed to cover a distance of 50 km using a small van with a 7.5 tonne capacity.

Co-products and waste: In the mayonnaise preparation stage egg whites are produced as a co-product (3.8 g). At the consumption stage, 80 g of food waste are generated, corresponding to 30% of the sandwich (WRAP, 2008).

20.2.4 Impact assessment

The results of the carbon footprint analysis of the packed lunch as modelled in the CCaLC2 tool are shown in Figure 43 and Figure 44. The total carbon footprint is 2.49 kg CO₂ eq. per packed lunch consumed by one person at a sandwich bar.

The raw materials, production and use stages contribute 45.3%, 31% and 23.1% of the total life cycle GHG emissions respectively.

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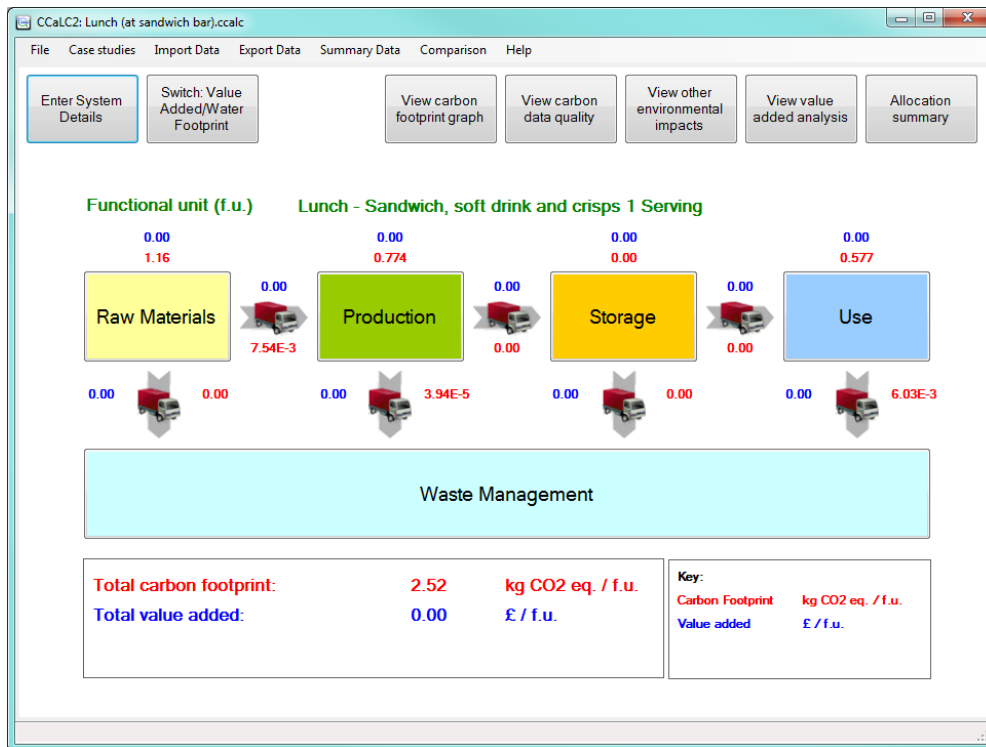


Figure 43 Carbon footprint of packed lunch



Figure 44 Life cycle stage contributions

References

- BSI, 2008. *Publicly Available Specification PAS 2050:2008. Specification for the assessment of the life cycle greenhouse gas emissions of goods and services*. British Standards Institution, London.
- WRAP, 2008. *The food we waste*. Waste and Resources Action Programme, Banbury, Oxon.

20.3 Packaging: Drinks Packaging

20.3.1 Introduction

This section provides a brief description of the packaging case studies in the CCaLC tool. A generic study of three different types of beverage packaging (HDPE and PET bottles and aluminium cans) used in the UK was carried out to analyse and compare their carbon footprint while also identifying the hot spots along the supply chain.

The LCA study follows the ISO 14044: 2006 and PAS 2050: 2008 methodologies as far as possible. The following sections describe the goal, system boundaries and inventory data used for the case studies.

20.3.2 Goal and scope of the study

Goal of the study: The main goal of this study is to provide a carbon footprint analysis of three types of packaging used in the UK:

- HDPE milk bottle (2.272 litre)
- PET water bottle (0.5 litre) and
- aluminium can for fizzy drinks (0.33 litre).

Functional unit: The functional unit of this study is defined as 'the packaging system required to deliver 1000 litres of beverage.

Scope and system boundary: The system boundaries of the study include 'cradle-to-grave' analysis for the packaging systems considered. As shown in Figure 45-Figure 48, the following life cycle stages are considered:

- raw materials extraction and production;
- packaging production and transport to filling site;
- tops and labels production and transport to filling site;
- filling of the packaging;
- distribution of the filled packaging to consumers;
- transport of post-consumer waste to waste management; and
- landfill, incineration and recycling of the waste packaging.

The following is excluded from the system boundary:

- energy used for storage at the retail stage;
- energy use at the consumption stage;
- carbon footprint of the beverage; and
- secondary and tertiary packaging.

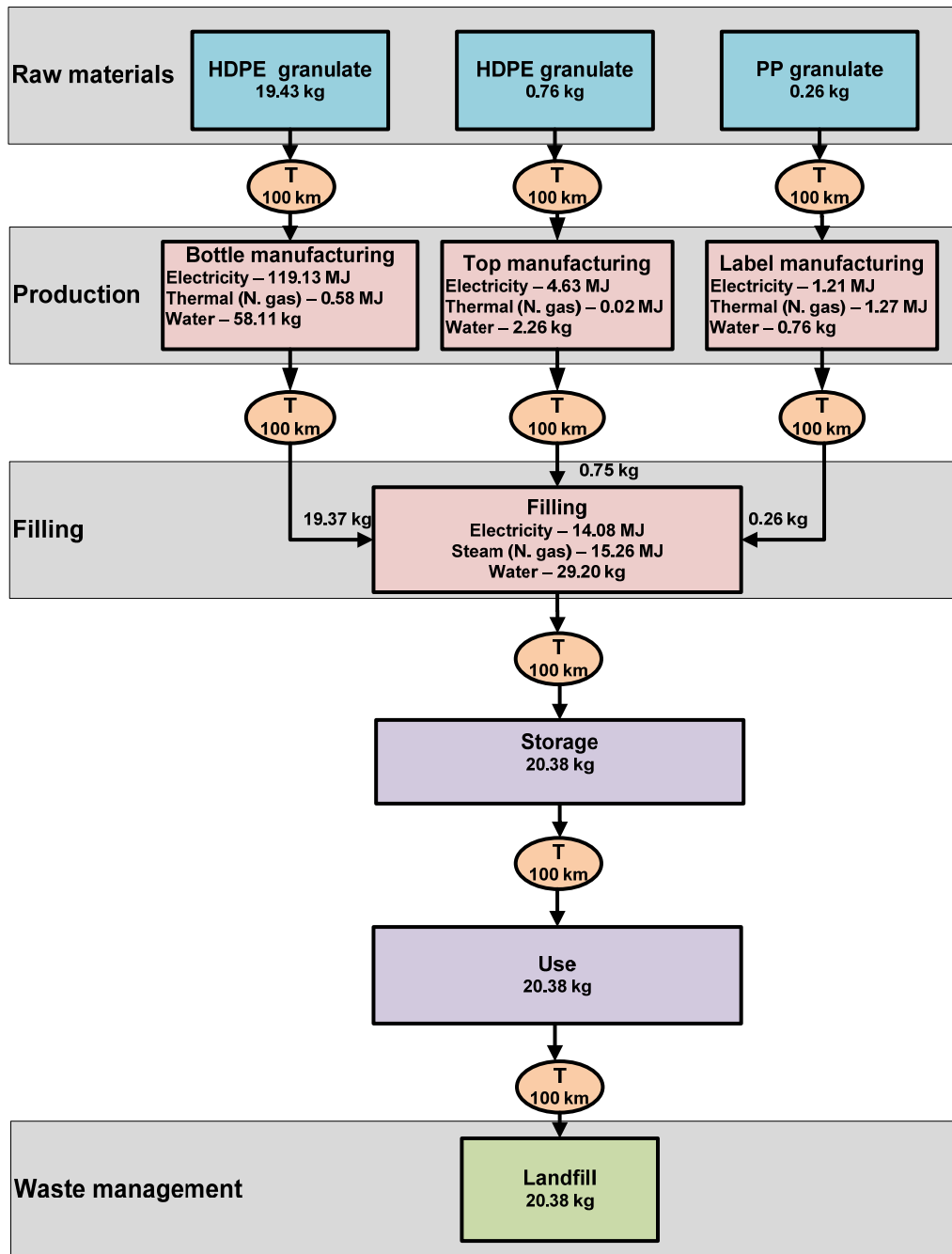


Figure 46 System boundary for the HDPE milk bottle (2.272 litre)

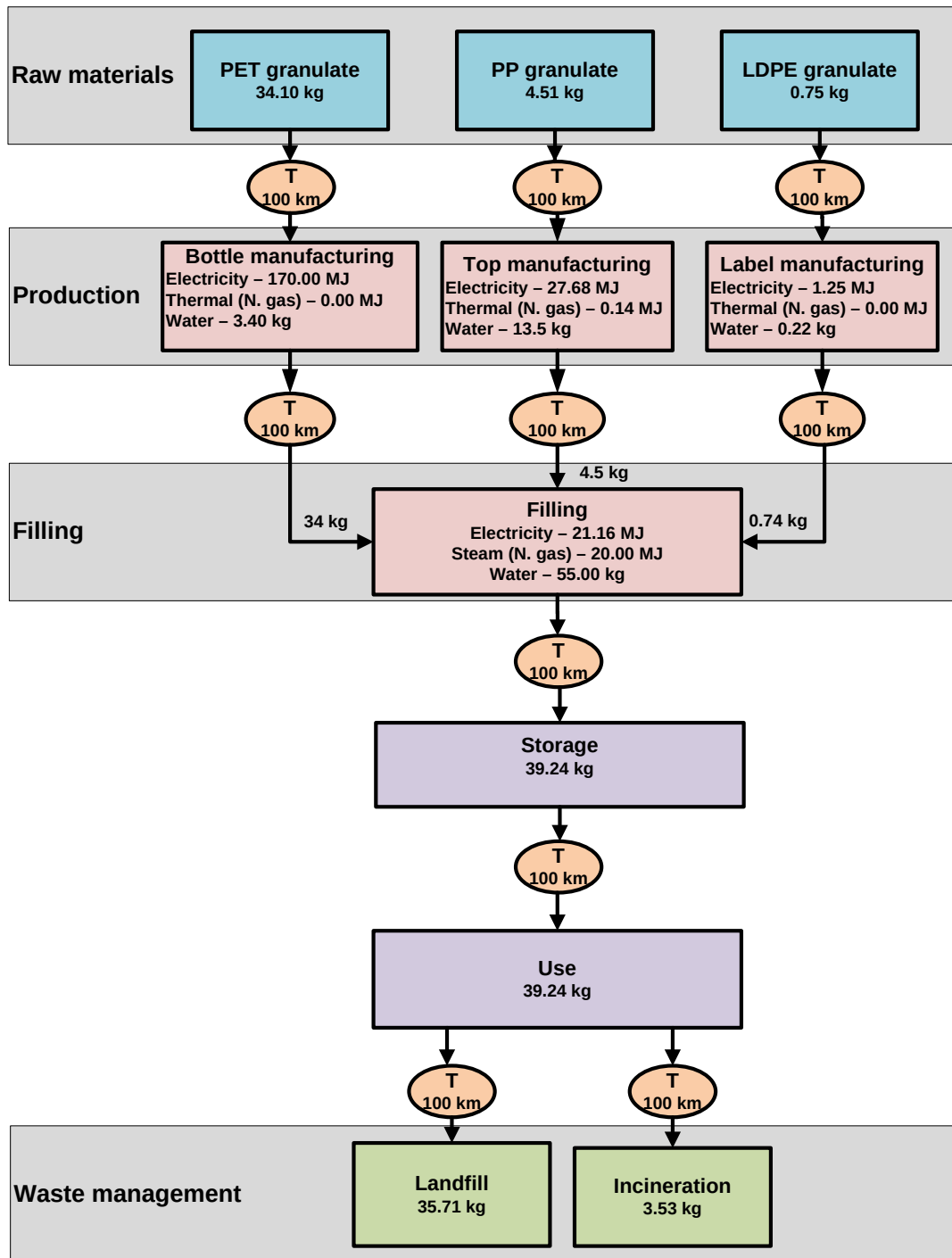


Figure 47 System boundary for the PET water bottle (0.5 litres)

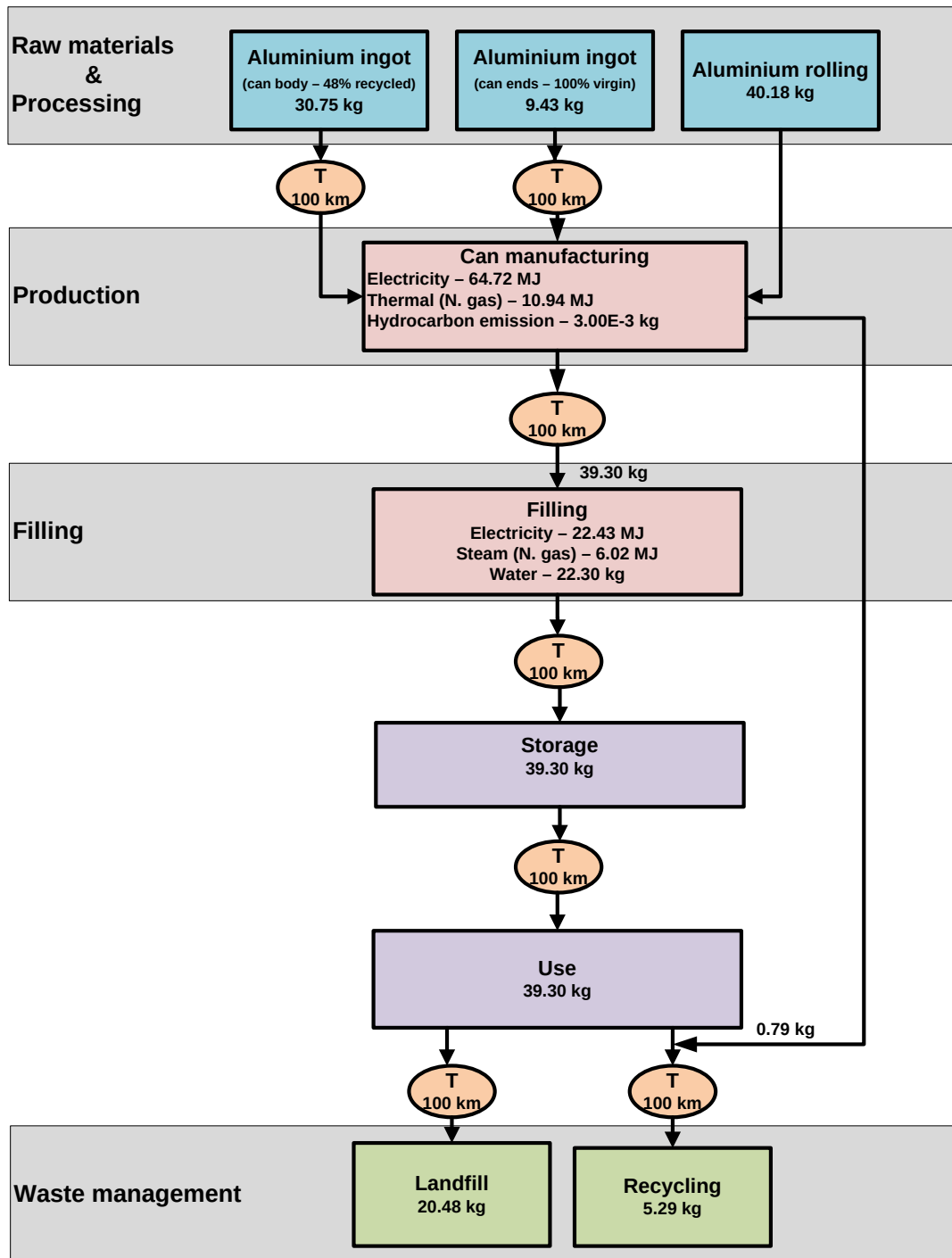


Figure 48 System boundary for the aluminium can (0.33 litre)

20.3.3 Inventory analysis

Description and weight of the packaging: The description and weight of the packaging types are shown in Table 6. The different packaging materials have been obtained from retail shops and weighted.

Table 6 Description and weight of the packaging materials

Description	HDPE bottle	PET bottle	Aluminium can
Type of beverage	Milk	Mineral water	Fizzy drink
Capacity (litres)	2.272	0.500	0.330
Number of bottles weighted	3	3	3
Average weight per bottle (g)	44	17	9.95 (can body) ¹
Material for top	HDPE	PP	AlMg3
Average weight of top (g)	1.71	2.25	3.05 (can end) ²
Material for label	PP film	LDPE film	N/A
Average weight of label (g)	0.58	0.37	N/A
Bottle weight per functional unit (kg per 1000 l)	19.37	34	30.15
Top weight per functional unit (kg per 1000 l)	0.75	4.5	9.24
Label weight per functional unit (kg per 1000 l)	0.26	0.74	N/A
TOTAL weight per functional unit (kg per 1000 l)	20.38	39.24	39.39

Manufacturing inventory: The manufacturing inventories for the packaging systems are shown in Table 7-Table 9. The manufacturing data for the HDPE and PET bottles have been estimated from Andrady (2003). The cans manufacturing data have been estimated from confidential sources.

Table 7 Manufacturing data for HDPE milk bottle (2.272 litres)

Inventory	Bottle manufacture	Tops manufacture	Label manufacture	Comments
Electricity (MJ per F.U.)	119.13	4.63	1.21	UK grid
Steam (MJ per F.U.)	0.58	0.02	1.27	Natural gas
Water (kg per F.U.)	58.11	2.26	0.77	

¹ The can body consists of 52% virgin and 48% recycled aluminium ingot (see Figure 48)

² The can end consists of 100% virgin aluminium ingot (see Figure 48)

Table 8 Manufacturing data for PET water bottle (0.5 litres)

Inventory	Bottle manufacture	Tops manufacture	Label manufacture	Comments
Electricity (MJ per F.U.)	170	27.68	1.25	UK grid
Steam (MJ per F.U.)	0.00	0.14	0.00	Natural gas
Water (kg per F.U.)	3.40	13.50	0.22	

Table 9 Manufacturing data for aluminium can (0.33 litres)

Inventory	Can manufacture	Comments
Electricity (MJ per F.U.)	10.94	UK grid
Thermal energy (MJ per F.U.)	64.72	Natural gas
Steel waste (kg per F.U.)	0.79	Sent to recycling
Hydrocarbon emission (kg per F.U.)	3.00E-03	

Filling stage: The energy (electricity and steam) and water requirement at the filling stage for the three packaging types were estimated from Schonert et al. (2002) and are presented in Table 10- Table 12.

Table 10 Energy and water data for filling the HDPE milk bottle

Inventory	Amount	Comments
Electricity (MJ per F.U.)	14.08	UK grid
Steam (MJ per F.U.)	15.26	Natural gas
Water (kg per F.U.)	29.20	

Table 11 Energy and water data for filling the PET water bottle

Inventory	Amount	Comments
Electricity (MJ per F.U.)	21.16	UK grid
Steam (MJ per F.U.)	20.00	Natural gas
Water (kg per F.U.)	55.00	

Table 12 Energy and water data for filling the aluminium can

Inventory	Amount	Comments
Electricity (MJ per F.U.)	22.43	UK grid
Steam (MJ per F.U.)	6.02	Natural gas
Water (kg per F.U.)	22.30	

Transport: All transport distances in the life cycle stages are assumed to be 100 km using 22 t trucks. The transport stages include:

- transport of raw materials to the manufacturing site;
- transport of packaging, tops/ends and labels from the manufacturing site to the filling stage;
- transport of the filled packaging from the filling site to storage at consumer, which includes transport to warehouse and retail centres;
- transport to landfill, incineration and recycling sites.

End of life scenarios: Different waste management scenarios have been considered for the different packaging materials in this study as shown in Table 13. Note that for the aluminium can closed loop recycling has been assumed for the can body so that allocation (through system expansion) is only carried out for the can ends.

Table 13 Waste management considered for the packaging systems

Type of waste management	HDPE bottle (%)	PET bottle (%)	Aluminium can (%)
Landfill	100	91	52
Incineration	n/a	9	n/a
Recycling	n/a	n/a	48
TOTAL	100	100	100

20.3.4 Impact assessment

The results of the carbon footprint analysis of the packaging as modelled in the CCaLC2 tool are shown in Figure 49-Figure 54. The carbon footprints of the three packaging are respectively 70, 186 and 295 kg CO₂ eq. per 1000 litres of beverage. The raw materials stage is the major hot spot for all three types of packaging, contributing 58%, 71% and 93% of the total carbon footprint for the HDPE, PET and Al containers, respectively.

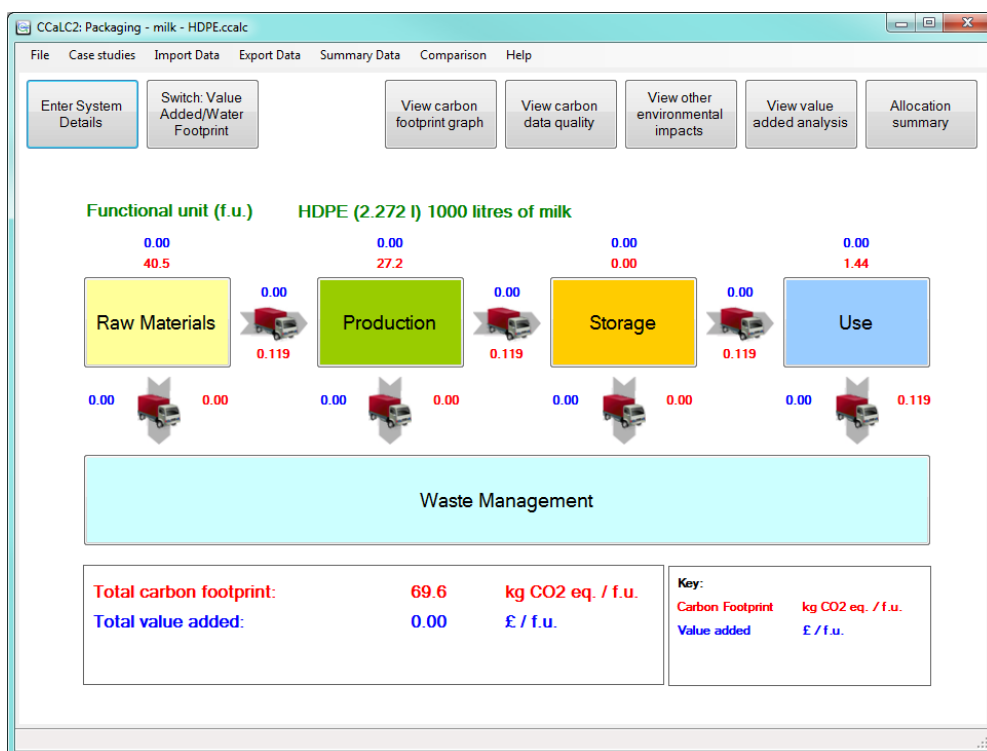


Figure 49 Carbon footprint of the HDPE milk bottle per 1000 l of milk packaged

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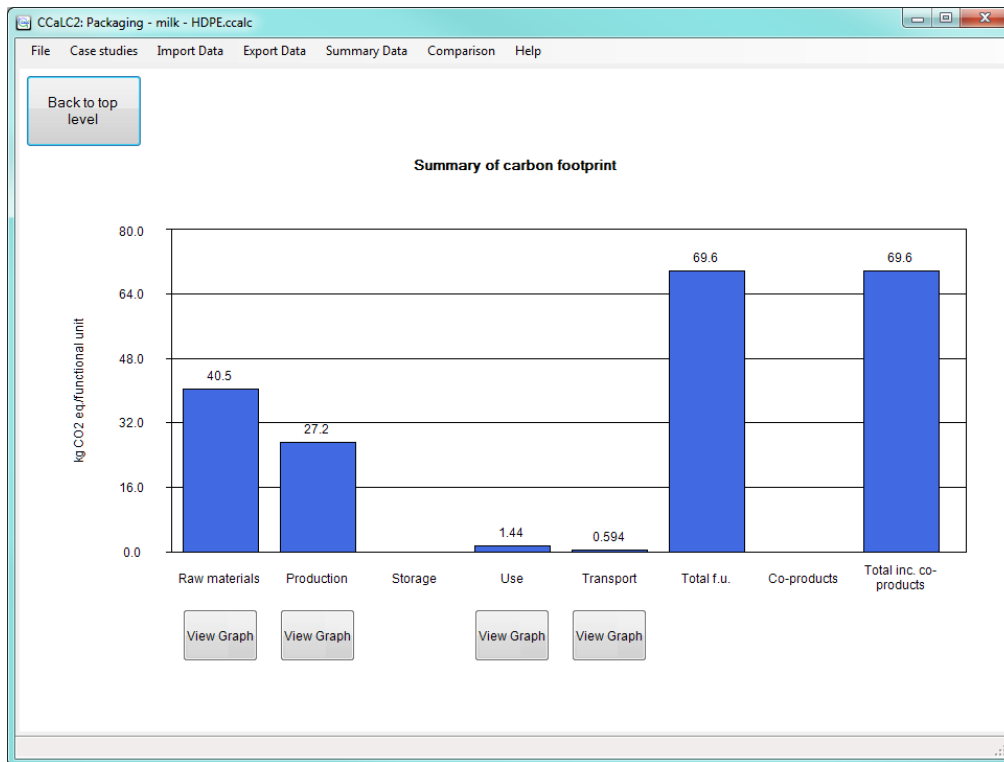


Figure 50 Carbon hotspots for the HDPE milk bottle (per 1000 l of milk)

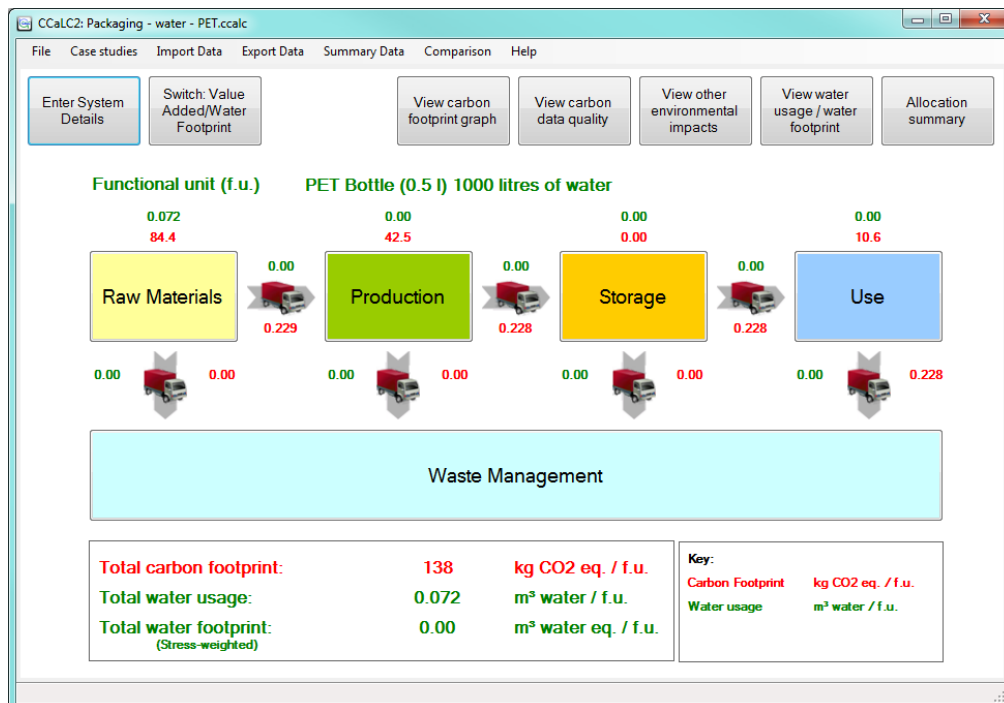


Figure 51 Carbon footprint of PET water bottle (per 1000 l of water)

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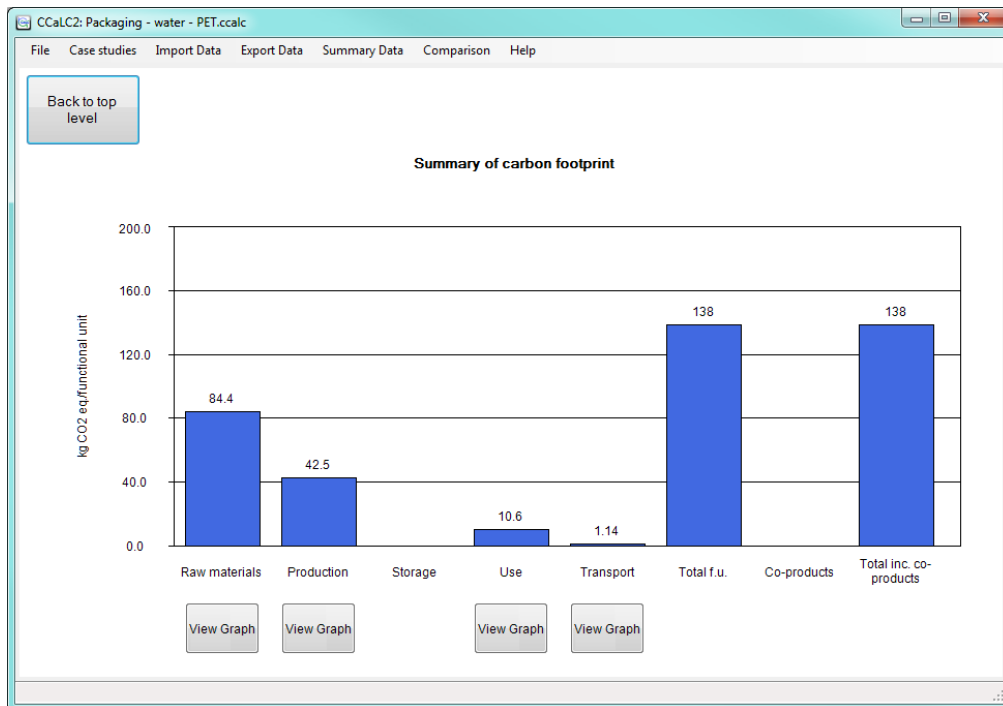


Figure 52 Carbon hotspots for the PET water bottle (per 1000 l of water)

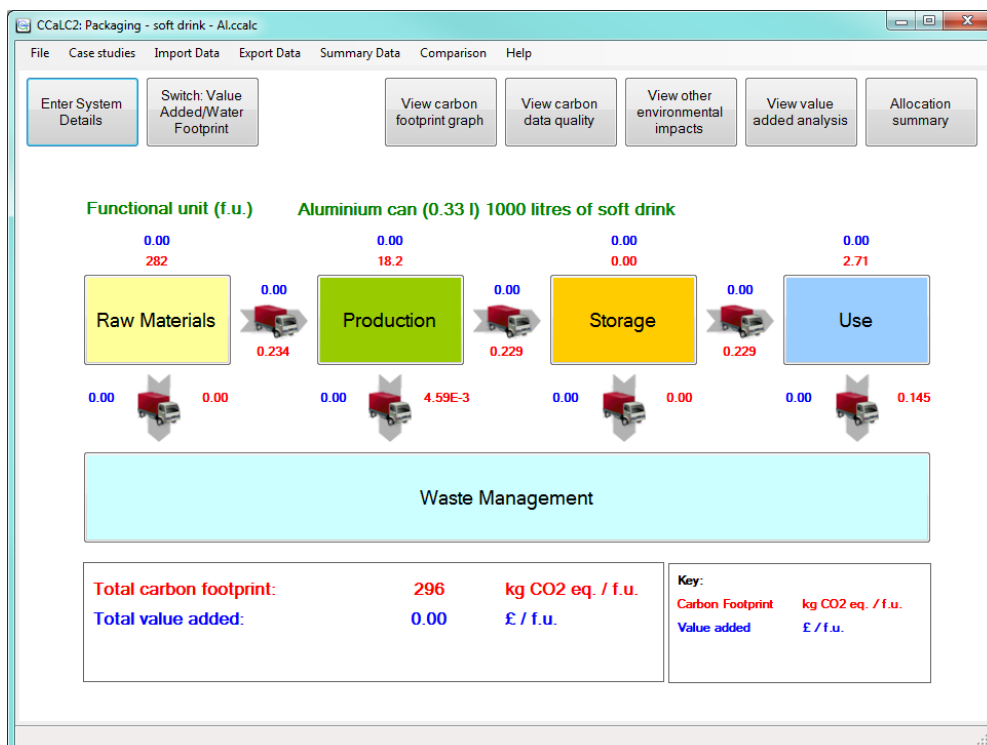


Figure 53 Carbon footprint of the aluminium can (per 1000 l of fizzy drink)

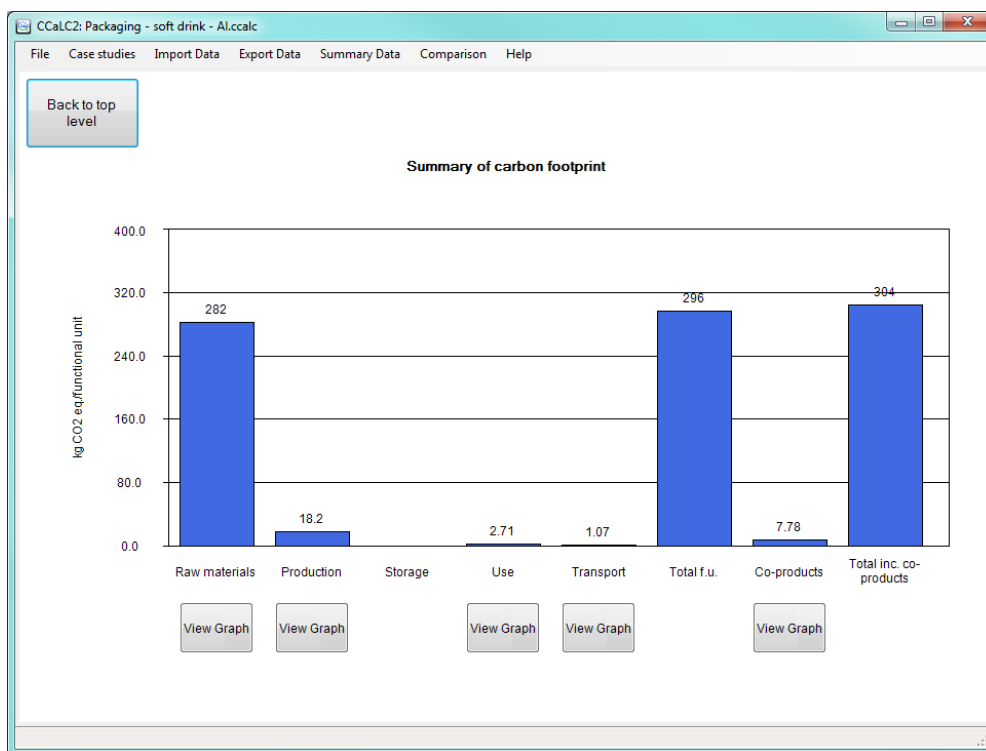


Figure 54 Carbon hotspots for the aluminium can (per 1000 l of fizzy drink)

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- ISO, 2006. "ISO 14044: Environmental management - Life cycle assessment - Requirements and guidelines". Geneva, 2006.
- Plastics Europe, 2006. "Eco Profiles: Life-Cycle Analysis." LCA database. <http://www.plasticseurope.org/Content/Default.asp?PageID=1170>.
- Schonert m., Motz G., Meckel H., Detzel A., Giegrich J., Ostermayer A., Schorb A., and Schmitz S., 2002. "Life cycle assessment for beverage packing systems II" in Germany. www.umweltdaten.de/publikationen/fpdf-l/2180.pdf.

Appendix 1 – Methodology for calculating the carbon footprint of transport

The carbon footprint of transport is calculated using the following equations:

NB. The following applies to datasets within the CCaLC database and does not apply to Ecoinvent data for which limited amount of information is available. For Ecoinvent datasets, the transport density is not variable.

The density of the material transported is used to ascertain whether the transport is mass or volume limited:

If $\rho_{\text{pack}} < M_{\text{max}}/V_{\text{max}}$ **then** Volume limited

Else, if $\rho_{\text{pack}} > M_{\text{max}}/V_{\text{max}}$ **then** Mass limited

For Volume limited cases the total mass transported per load is:

$$M_{\text{trans}} = \rho_{\text{pack}} * V_{\text{max}} * f$$

For Mass limited cases the total mass transported per load is:

$$M_{\text{trans}} = M_{\text{max}} / \rho_{\text{pack}} * f$$

The number of functional units is then calculated per load:

$$f.u.\text{-load} = M_{\text{trans}}/M_{\text{material}}$$

The carbon footprint per functional unit is then calculated:

$$c.f. = c.f.\text{-load}/f.u.\text{-load}$$

where:

ρ_{pack} is the packing density as defined by the user

M_{max} is the maximum transported mass

V_{max} is the maximum transported volume

M_{trans} is the total mass transported per load

f is the load factor (i.e. % loaded)

$f.u.\text{-load}$ is the number of functional units per loaded vehicle

M_{material} is the mass of material transported per functional unit

$c.f.\text{-load}$ is the carbon footprint of the vehicle at the current load

c.f. is the carbon footprint per functional unit

For trucks returning empty, the carbon footprint per functional unit is augmented by the ratio of the carbon footprint of the vehicle when it is loaded and when it is empty, i.e.:

$$c.f._{total} = c.f. + c.f. * [(c.f._{empty} / c.f._{load})]$$

where:

c.f._{total} is the total carbon footprint per functional unit

c.f. is the carbon footprint associated with transporting the material mass

c.f._{empty} is the carbon footprint of the vehicle when running unloaded

Appendix 2 – Data quality criteria

A2.1 General about LCA data quality

According to PAS2050, the following data quality requirements should be considered when performing an LCA:

- time related coverage;
- geographical coverage;
- technology coverage;
- precision and accuracy;
- completeness;
- consistency;
- reproducibility; and
- sources of data (primary or secondary).

Thus, data quality assessment is a complex task as multiple aspects need to be considered, including the context in which the data are used. Enough information on the data is therefore fundamental to avoid their misinterpretation or misuse.

A2.2 Data quality assessment in the CCaLC2 tool

The quality of data within the CCaLC2 tool can be defined by a user as:

- High
- Medium or
- Low.

To help the user determine whether their data are of High, Medium or Low quality, a methodology specific to CCaLC has been developed using the data quality criteria mentioned in the previous section. The criteria used in the methodology are summarised in Table A2.1. Table A2.2 shows how these can be aggregated to arrive at an overall Data Quality Indicator (DQI) - High, Medium or Low. For these purposes, each data quality criterion is assigned a weight of importance on a scale of 1-10. For example, as shown in Table A2.1, “Age of data” has the weight of 2, being twice as important as the geographical origin of data. Each data quality indicator is assigned (an arbitrary) maximum score for each criterion: e.g. the High indicator has a score of 3, Medium has 2 and Low has a score of 1 (see Table A2.2). Applying the weights of importance for each criterion and its maximum score for the respective quality indicators, the maximum score for each quality indicator is:

- 30 for High;
- 20 for Medium; and
- 10 for Low.

For the purposes of the analysis in the CCaLC2 tool, the following score ranges have been adopted for the data quality assessment:

- Low data quality: score in the range of 1-10;
- Medium data quality: score in the range of 11-20; and
- High data quality: score range of 21-30.

An example shown in Table A2.2 shows an overall score of 19, indicating Medium data quality (noting that the overall score for Medium quality is between 11-20).

Table A2.1 Matrix of Data Quality Indicators (DQI) for the CCaLC2 tool

Data quality criteria	Data quality indicators		
	High	Medium	Low
Age of data	< 5 years	5 - 10 years	> 10
Geographical origin of data	Specific	Partly specific	Generic/average
Source of data	Measured and/or modelled based on specific data (e.g. the company data or from suppliers)	Modelled using generic data from LCA databases; <u>some</u> data derived using expert knowledge	<u>Mainly</u> sourced from literature and/or estimated and/or derived using expert knowledge
Completeness of data	All inputs and outputs considered	Majority of relevant inputs and outputs considered	Some relevant inputs and outputs considered or known
Reproducibility /reliability/ consistency of data	Completely reproducible/reliable/ consistent	Partly reproducible/reliable/ consistent	Not reproducible/ not known

Table A2.2 Aggregating individual Data Quality Indicators (DQI) to arrive at an overall DQI (High, Medium or Low)

Data quality criteria	Weighting for each criterion on a scale 1-10*	High quality Max. score for each criterion: 3	Medium quality Max. score for each criterion: 2	Low quality Max. score for each criterion: 1	Example data quality assessment
Age	2	3	2	1	1 (Low)
Geographical origin	1	3	2	1	3 (High)
Source	3	3	2	1	2 (Medium)
Completeness	2	3	2	1	3 (High)
Reproducibility /reliability/ consistency	2	3	2	1	1 (Low)
Maximum score		30 (max score) Overall score for High in the range: 21-30	20 (max score) Overall score for Medium in the range: 11-20	10 (max score) Overall score for Low in the range: 1-10	19 (overall score) Data quality indicator: Medium

*The sum of all weights is 10.

NB: The overall score of 19 has been calculated in the following way:
 Overall score = $2*1+1*3+3*2+2*3+2*1 = 19$
 Therefore the overall data quality indicator = Medium

It should be noted that the overall data quality will depend on both the quality of the particular datasets used by the user as well as on the confidence the user places on the quantity/amount of materials, energy etc. they are defining for each sub-system.

For example, the quality of the background dataset for UK electricity mix and the related carbon footprint may be High; however, the user may not be confident in the data related to the amount of electricity used in a particular sub-system so that the quality of this datum may be Medium or Low. In this case, since the data quality for the set is already defined (as high), the user will only need to specify the quality for the quantity/amount and the tool will calculate the overall data quality for that particular sub-system. The process is repeated for each sub-system.

The approach used for calculating DQI for a sub-system is shown in Table A2.3. Note that the quantity/amount is considered more important here than the quality of the dataset.

Table A2.3 Aggregating the Data Quality Indicators (DQI) to arrive at an overall DQI for each sub-system

DQI for user-defined dataset*	DQI for the amount/quantity entered in the CCaLC2 tool by the user	Data quality of each sub-system (DQS)
High	High	High (3)
Medium	High	High (3)
Low	High	Medium (2)
High	Medium	Medium (2)
Medium	Medium	Medium (2)
Low	Medium	Medium (2)
High	Low	Medium (2)
Medium	Low	Low (1)
Low	Low	Low (1)

*Note that the datasets already available in the tool have a predefined DQI so that the user only needs to define the quality of their own datasets.

Once the data quality indicators have been calculated for each sub-system, a weighted approach is then applied for assessing the overall data quality of the whole system based on the percentage contribution of each life cycle stage to the total carbon footprint. The overall data quality for the whole system is therefore calculated as:

$$DQ_{CF} = \sum_{n=1}^N I_n \left(\sum_{m=1}^M DQS_m \right)$$

where:

DQ_{CF} - overall data quality of the system

I_n – percentage contribution of each life cycle stage to the total carbon footprint (%)

DQS_m – data quality (1, 2 or 3) for sub-system m

For the purposes of the analysis in the CCaLC tool , the following ranges have been adopted for the overall data quality of the whole system:

- Low data quality: $DQ_{CF} = 100 - 166$;
- Medium data quality: $DQ_{CF} = 167 - 233$; and
- High overall data quality: $DQ_{CF} = 234 - 300$.

Appendix 3 – Water use and water footprint

A3.1 Water use

The water use represents the sum of all the water consumed in a supply chain, comprising blue and green water.

Blue water use refers to consumption of freshwater from rivers, lakes and aquifers. Water consumption indicates the freshwater withdrawals which are evaporated, discharged into different watersheds or the sea after use and embodied in products and waste.

Green water is the amount of rainwater (stored in the soil as soil moisture) used by plants is referred to as green water. Its relevance is significant in the case of agricultural systems.

A3.2 Water footprint (stress-weighted)

The water footprint (stress weighted) is calculated according to the midpoint impact assessment method proposed by Pfister et al. (2009)³. This method assesses the environmental impacts of freshwater consumption by incorporating Water Stress Index (WSI) as a mid-point characterisation factor. WSI indicates the water consumption impacts in relation to the water scarcity. This method considers only blue water consumption. Therefore, the water footprint is calculated as below:

$$\text{Water footprint (m}^3 \text{ eq./f.u.)} = \text{Blue water use (m}^3 \text{/f.u.)} \times \text{WSI}$$

The CCaLC2 tool contains WSI values for all countries at a national level. The WSI values, which range from 0.01 to 1, are derived using the following equation:

$$WSI = \frac{1}{1 + e^{-6.4 WTA^* \left(\frac{1}{0.01} - 1 \right)}}$$

where WTA* is a modified WTA to account for monthly and annual variability of precipitation.

³ Pfister, S., Koehler, A., Hellweg, S., 2009. Assessing the environmental impacts of freshwater consumption in LCA. *Environmental Science & Technology*, 43 (11), 4098-4104.